PHYSICAL AND NATURAL

THERAPEUTICS:

THE REMEDIAL USES OF ATMOSPHERIC PRESSURE, CLIMATE, HEAT AND COLD, HYDROTHERAPEUTIC MEASURES, MINERAL WATERS, AND ELECTRICITY.

BY

GEORGES HAYEM, M.D.,

PROFESSOR OF CLINICAL MEDICINE IN THE FACULTY OF MEDICINE OF PARIS.

EDITED BY

HOBART AMORY HARE, M.D.,

PROFESSOR OF THERAPEUTICS AND MATERIA MEDICA IN THE JEFFERSON MEDICAL COLLEGE OF PHILADELPHIA.

WITH 113 ILLUSTRATIONS.

EDINBURGH AND LONDON:
YOUNG J. PENTLAND.
1895.

PREFACE.

EVERY practising physician constantly sees cases which should be sent to a health resort, there to gain the benefits of the mineral waters or change of climate. In other instances he sees clearly that remedial measures, such as the application of heat and cold, baths, or electricity, will be of greater advantage to his patient than the administration of drugs.

Information concerning such resorts and methods has been scattered and fragmentary, and as a result they have been too much ignored. The object of this book is to provide in a concise form just what the physician needs in this respect. Written by one of the foremost therapeutists of the day in Europe, it embodies not only his own views, but also those held by Beni-Barde, Fleury, the brothers Delmas, and Winternitz in the Chapter on Thermic Agents; von Vivenot, Lombard, H. Weber, and Lindslay in the Chapter on Aërotherapy and Climate; and by Durand Fardel, Leichtenstern, Le Bret, and Rotereau on Mineral Springs. In the portion devoted to Electricity the views of standard writers are linked with those of the author.

It has been the aim of the Editor to render the text applicable to the needs of the American physician, particularly by the addition of articles on American Climate and Mineral Springs, and in this effort he trusts he has succeeded.

222 SOUTH FIFTEENTH STREET, PHILADELPHIA.

CONTENTS.

PART I.

ATMOSPHERIC PRESSURE AS A THERAPEUTIC AGENT.

It is a well-known fact that the higher we rise above the level of the sea the more rarefied becomes the atmosphere, and the less the pressure upon the surface of the body. At an altitude of 5500 metres the weight of a litre of air is only half as much as at the sea-level, and conversely there is an increase of pressure and in air-density as we descend below the level of the sea.

Each condition, that of augmented and that of diminished atmospheric pressure, brings about modifications in the gaseous interchanges in the lungs and tissues, and consequently in the functions of the body. For this reason altitude constitutes a very important factor of climate, one which must always be taken into account when we study climate from a therapeutic standpoint.

Very ingenious apparatus is now manufactured which to some extent obviates the necessity of a change of residence, and enables the patient in some instances to obtain at home the requisite modifications of atmospheric pressure. The application of these artificial means for therapeutic ends constitutes *aërotherapy.*

The methods employed in aërotherapy create conditions which differ sensibly from those produced by a change of altitude, for we are able at will to provide compressed or rarefied air, while residence on a mountain supplies only the latter. Again, the influence of climate is continuous; but in the case of aërotherapeutic measures the duration of compression and of rarefaction of the atmosphere can be controlled and limited. Finally, we can permit the aërotherapeutic agents to act upon a single part, as, for example, the respiratory system, or upon the entire surface of the body.

The bath of compressed air is patterned after and was suggested by the diving-bell. According to Aristotle, it was known in his day, although its discovery is generally attributed to Sturmius, who lived in the sixteenth century.

In 1786, Smeaton made use for the first time of the force-pump, with the purpose of supplying a diving-bell with the air necessary for respiration.

The effects of compressed air upon the ear and upon respiration were noted by Hamel in 1820; somewhat later Colladon recorded the cure of a diver, whose breathing had been labored, by means of the diving-bell.

The thought to supply compressed air for therapeutic purposes was first conceived by Tabarie in 1832; but his observations were not published until 1838. Junod, in 1835, described the first aërotherapeutic apparatus. He knew that respiration was facilitated by compressed air, that the vital capacity of the lung was increased, and that inspirations became deeper and less frequent. But in his apparatus compression and expansion were effected suddenly. On this account his method was severely criticised by the Academy of Sciences, largely in consequence of a report made upon the method by Magendie.

In 1840, Tabarie founded the first establishment for aërotherapy at Montpellier. To him and to Pravaz, of Lyons, is due the credit for solving the practical difficulties of the method. They laid stress upon the importance of improving the air and removing the pressure in a gentle and gradual manner, and designed appropriate apparatus to attain such a result.

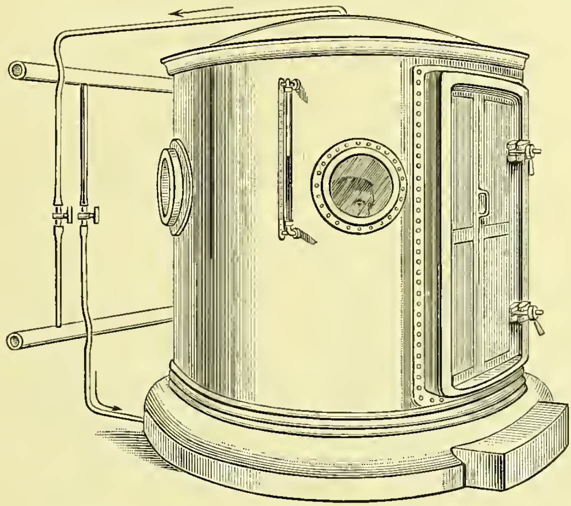
An excellent study of the physiological effects of this method of treatment has been made by von Vivenot.

Although this method originated in France, it gained its first foothold elsewhere, particularly in Austria, Sweden, Scotland, Italy, Denmark, and Russia. Numerous establishments were founded in these countries. At the present time the method is also popular in France.

The bath of compressed air is administered in pneumatic chambers constructed upon the principles of the diving-bell of Smeaton. In France Tabarie's apparatus, as modified by Fontaine, is the most popular. (Fig. 1.) It represents essentially a bell and a force-pump. The bell consists of a cylinder and two hemispherical end-plates; it has a capacity of 8 cubic meters, and is closed by a door that opens from without inward. A U-shaped tube, one branch of which is within the chamber and one without, and which is half-filled with mercury, indicates the pressure that obtains in the chamber. The chamber is also provided with two other tubes—one for supplying air, the other

for ventilation. The former is connected with the hydraulic compressor of Fontaine, constructed after the one employed in the mines of Chemnitz. The air escapes through the ventilating-tube, which arises from the upper part of the chamber. At a single sitting of two hours an individual consumes 8000 litres of air. The changes

Fig. 1.



Fontaine's Modification of Tabarie's Pneumatic Chamber.

in pressure are effected very gradually by means of stopcocks, and, as a rule, an increase of pressure corresponding to two-fifths atmosphere is not exceeded.

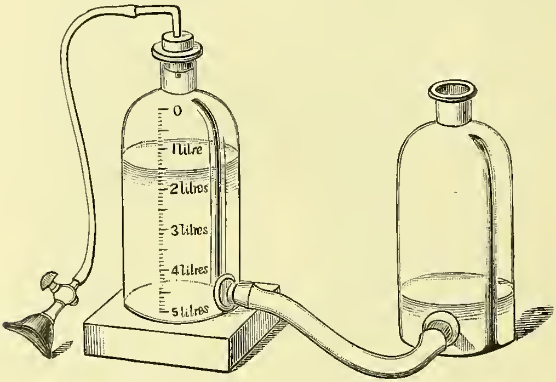
Physiological Effects. In studying the effects of compressed air, we shall confine ourselves solely to the consideration of those produced by the aërotherapeutic apparatus.

As the results of treatment by compressed air make themselves felt especially upon the respiratory organs, it is important to understand how the variations in the vital capacity of the lungs and in the forces of expiration and inspiration are estimated. The vital capacity of the lungs is measured by an apparatus known as the spirometer; that invented by Hutchinson, and first modified by Wintrich and subsequently by Schnepf, is the one most widely employed. Recently the spirometer of Galante has come into extensive use.

Instead of these somewhat delicate instruments, which have the fault that they do no always register correctly, Dupont proposes the

use of a simple apparatus consisting of two bottles connected at their lower parts by a rubber tube, as shown in Fig. 2. These bottles should have a capacity of 4 litres (4 quarts). One of them is graduated in cubic centimetres, and is closed above with a perforated rubber cork, through which a right-angled glass tube is passed. A rubber tube, provided with a stopcock and terminating in a funnel-shaped mouthpiece, is attached to the glass tube.

FIG. 2.



Dupont's Respiration Bottles.

The open bottle is filled with water and then elevated so that the water flows into the second bottle up to the line marked zero. The stopcock is now closed, and the two bottles are placed upon the same plane. The patient takes an inspiration and applies his mouth to the funnel, opens the stopcock, and expires into the bottle. At the end of the expiration the stopcock is again closed. When the two bottles are so placed that the water in them is at the same level, the amount which is thereby made to flow into the graduated bottle indicates the volume of expired air at the pressure of the atmosphere.

The method is not absolutely accurate, but commends itself on account of its simplicity.

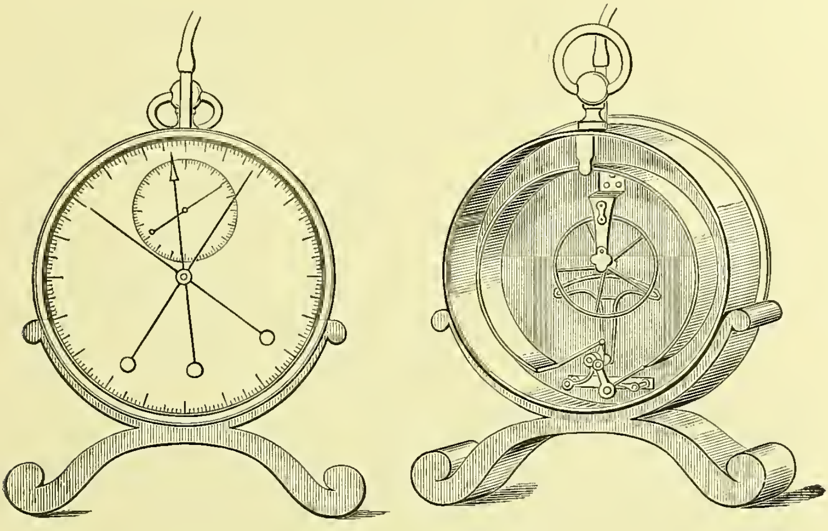
The expiratory and inspiratory forces are determined by means of the pneumometer or pneumotometer.

Marchal's pneumotometer consists essentially of a manometric tube, representing almost a complete circle, and communicating at its upper portion with a mouthpiece, from or into which inspiration or expiration is made according as the force of one or the other is to be

measured. Index needles serve to mark the diminution and the increase in pressure. (Fig. 3.)

If the inspiratory force is to be determined, the needle is placed on the side marked inspiration, and with it also one of the maximal needles. Then, having made a strong expiration, the person applies the lips hermetically against the mouthpiece and takes the deepest inspiration possible. The index needle is displaced, carrying the maximal needle with it; the latter remains at the extreme point, but the former quickly rebounds. The number of degrees indicated by

FIG. 3.



Marchal's Pneumotometer.

the maximal needle corresponds to the pressure in centimetres of mercury.

To measure expiration the stopcocks are reversed, and the needle, carrying a maximal needle with it, is placed on the corresponding side. The subject after taking the strongest possible inspiration expires forcibly, and the second maximal needle indicates the result of the effort.

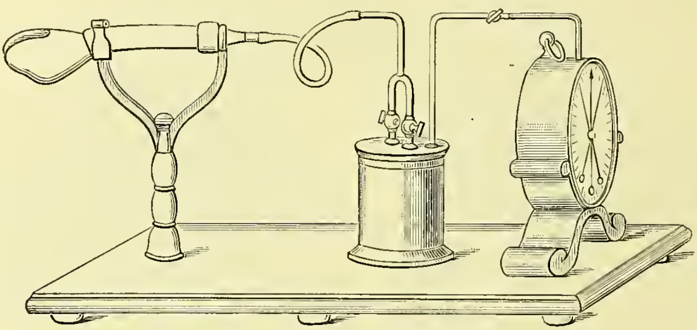
With all forms of apparatus errors are possible; it is important, therefore, always to use the same instruments and to employ them under identical conditions in order to obtain results that are comparable.

As a rule, the inspiratory effort is less powerful than the expiratory; according to Marchal, the ratio is 2 to 3.

Moreover, the result of the effort is not necessarily proportionate to the vital capacity, for the muscles of respiration may be vigorous in one possessing a relatively small vital capacity, and *vice versa.*

By a different process Brunniche has arrived at analogous results. Using the Waldenburg apparatus he found that a healthy adult with 10 inspirations depressed the cylinder 50 c.cm., while he elevated it to the same extent with only 7 expirations. Hence the inspiratory force is only seven-tenths of that of expiration, or a ratio agreeing very closely with that obtained by Marchal.

FIG. 4.



Marchal's Pneumotometer.

When this ratio is modified it is the inspiration which is found to be relatively diminished by means of the existence of pulmonary lesions, or sometimes of a simple functional insufficiency of the upper parts of the lungs.

Effects of the Air-bath. The first effect of the compressed air-bath is exerted upon the ears, and depends upon differences in pressure on the two surfaces of the tympanum.

Patients generally complain of slight pain and buzzing; the pain is not intense unless catarrh of the Eustachian tubes exists. After a short time equilibrium is re-established, but a slight impairment in acuity of hearing persists.

The voice is altered, becoming a little higher; whistling is difficult. There is also a slight diminution in the sharpness of taste, smell, and touch; and the patient grows somewhat somnolent. Foleif, however, has observed in some cases a state of cerebral excitement, with loquacity.

During the rise of the atmospheric pressure the space occupied by the intestinal gases, as Panum has pointed out, diminishes, the entrance of air into the thorax being correspondingly facilitated. This, according to P. Bert, is the only mechanical action produced by the compressed air-bath. However this may be, the respiratory movements become more ample and undergo a change in rhythm. Inspiration is rendered easier, expiration more difficult. The ratio, normally 4 : 5, becomes 4 : 6, 4 : 8, or even 4 : 11. The number of respirations is diminished, a phenomenon that persists for a time after the bath.

During the period of constant pressure the number of respirations is decreased three a minute, according to some authorities, but P. Bert states that he has not been able to observe any notable difference in the number of respirations.

The increased amplitude of the movements leads to an enlargement of the chest. Von Vivenot, in experiments upon himself, has noted an increase in the size of his thorax, as follows : After 20 minutes, 3.29 mm.; after 2 hours, 4.85 mm.; after 5 sittings, 6.59 mm.; after 17 sittings, 9.47 mm.

The spirometer shows, moreover, an increase in the volume of the respired air, amounting, as Panum has determined, to 270 c.cm. after the first bath, and augmenting after the second.

The vital capacity likewise experiences an increase, which, in the mean, is 100 c.cm., being most rapid in the beginning of the treatment. In Von Vivenot's experiments the vital capacity within three months increased 700 c.cm. Bert's experiments showed an increase of 7 per cent., while those of Regnard showed 11 per cent. Bert, however, holds that the pulmonary respiration in spite of this increase is not notably modified, since the fall in the number of respirations counterbalances the increase in the capacity of the lungs.

Pravaz has shown that in order to obtain the best effects upon the respiration it is essential not to raise the pressure more than 38 c.cm. of mercury. In practice it is not customary to exceed 30 c.cm., and for women and children the pressure employed is even less.

The influence of the heightened atmospheric pressure upon the skin and mucous membranes generally makes itself felt by anæmia of these parts, the blood being driven to the deeper tissues.

The effects upon the pulse are, according to Pravaz, a transient and slight primary increase in its rate, followed by retardation.

Von Vivenot gives as another effect the flattening of the sphyg-

mographic tracing, with a disappearance of the dicrotic wave. This phenomenon has not been satisfactorily explained. P. Bert in his experiments did not observe it. In dogs he obtained an elevation of the arterial tension, but, as he employed much greater pressures than are used in therapeutics, the results cannot be accepted as conclusive. Nevertheless, it is probable that the work of the heart is increased in the compressed-air apparatus. It has been averred that the lymphatic circulation is also influenced, but such an effect has not been demonstrated.

While some writers, especially the Germans, have attributed the effects of compressed air to mechanical actions, Bert sought to prove that they were the result of chemical changes produced by the entrance of the atmospheric gases into the organism through the medium of the blood. The increased tension of the oxygen and nitrogen, he asserts, leads to modifications in the gäseous constituents of the blood, and indirectly to changes in the nutritive processes, but it must surely be admitted that under the conditions of the compressed-air bath the chemical action which P. Bert invokes is restricted, and only a part of the general effect can be justly attributed to it.

Paul Bert in his experiments has clearly elucidated the nature and causes of the accidents resulting from exaggerated and from greatly reduced pressures, but in practice different conditions obtain. In those experiments in which he remained within the limits of the pressure used in therapeutics, he noted only a very slight increase of oxygen in the blood. This slight increase did not coincide with any sensible modification in the excretion of carbon dioxide.

Von Vivenot has obtained a mean increase of 1° in temperature during the compressed-air bath, but as Stembo records a similar decrease, the point remains yet to be settled.

The researches in regard to the excretion of nitrogen are not sufficient. Pravaz and Hadra state that there is an increase in the urea excreted, whereas Fränkel denies this; so that the influence of compressed air on nutrition is probably not great. Nevertheless, its use exerts an effect upon the general health in a circuitous way. It increases the appetite and hastens digestion. Both the sick and the well during the use of the treatment eat more and digest better. After a certain time the body-weight is found to be increased, although after every individual sitting a diminution of 40 to 225 grams is observed. When the regimen of a group of patients was identical,

Simonoff and Katschenowsky noted a loss in weight, but when the patients were allowed to follow their own inclinations the weight increased. In this respect the effects are analogous to those following the inhalation of oxygen.

In conclusion, the pneumatic treatment favors rather than retards general nutrition; after a variable period of fatigue it causes an increase in strength and weight, and especially an increase in the power of the respiratory muscles. In addition, it exercises a sedative influence upon the nervous system.

The duration of a bath of compressed air is generally two hours; of this a half-hour is employed for raising the pressure to the desired height, for another half to one hour it is kept constant, and during the remaining time it is gradually decreased. Ventilation should be active throughout the procedure.

The elevation of pressure is ordinarily two-fifths to three-sevenths atmospheres (30 to 33 c.cm. of mercury). In the case of feeble persons a fifth of an atmosphere (15 to 16 c.cm. of mercury) is not exceeded.

The duration of the treatmeat varies, and from twenty to more *séances* are necessary to obtain a permanent result.

It is customary to give one *séance* a day in the beginning; toward the end of the treatment one every two or three days suffice.

Advancing emaciation, as well as an exaggerated appetite, are indications for the cessation of the treatment.

Compressed air is useful in many affections. In diseases of the respiratory apparatus it is valuable by reason of its mechanical effects, while in constitutional diseases advantage is taken of its influence upon general nutrition.

To its mechanical effects we may attribute (1) the diminution of pulmonary congestion in acute and chronic inflammations of the bronchi; (2) the reduction in secretion from the respiratory mucous membrane; (3) the absorption of inflammatory exudates, especially those of pleurisy; (4) the augmented capacity of the lungs in emphysema, chronic catarrh, chronic pneumonia, and in certain forms of phthisis; (5) the increase in power of the respiratory muscles.

To the chemical effects may be ascribed (1) the increased absorption of oxygen, the utility of which is manifested in dyspnœic states, and, more doubtfully, in anæmia; (2) the greater activity in the processes of oxidation, which is of value in obesity, diabetes, rheumatism, and the convalescent state; (3) the sedative action on the ner-

vous system, for which the increased absorption of atmospheric nitrogen is perhaps responsible.

Many patients subjected to the treatment by compressed air have, in addition to emphysema and chronic bronchitis, a more or less pronounced cardiac affection. When the contractions of the heart are strong no accident need be feared, but when the myocardium is weak the treatment should not be employed. Diseases of the kidney, the spinal cord, the liver, and the intestines have been considered contraindications to the treatment on account of the congestion which it engenders in these organs. But this is a purely theoretical view. The existence of a moderate fever, such as obtains in the subacute diseases of the air-passages, does not contraindicate resort to the treatment. When, however, the fever is high or hectic in type the use of compressed air should be suspended or entirely abandoned.

The bath of compressed air mentioned already necessitates the employment of a ponderous apparatus, such as can only be used in special establishments. Moreover, by this method, as it acts upon the entire body, the respiratory system is not very markedly influenced. The so-called portable apparatuses that have been devised are less complicated, and exert their mechanical effects more directly upon the lungs. In their application the active collaboration of the patient becomes a factor, but as the manipulation of the apparatus is simple this causes him no inconvenience.

The portable apparatus should be so constructed that the air can be compressed or rarefied at will, for it thus furnishes a form of respiratory gymnastics. More varied effects can be produced by this apparatus, and it fulfils more indications than the compressed air-bath.

The effects the apparatus enables us to produce are:

(1) Increase of intra-thoracic pressure by inspiration of and expiration into compressed air.

(2) Diminution of intra-thoracic pressure by inspiration of and expiration into rarefied air.

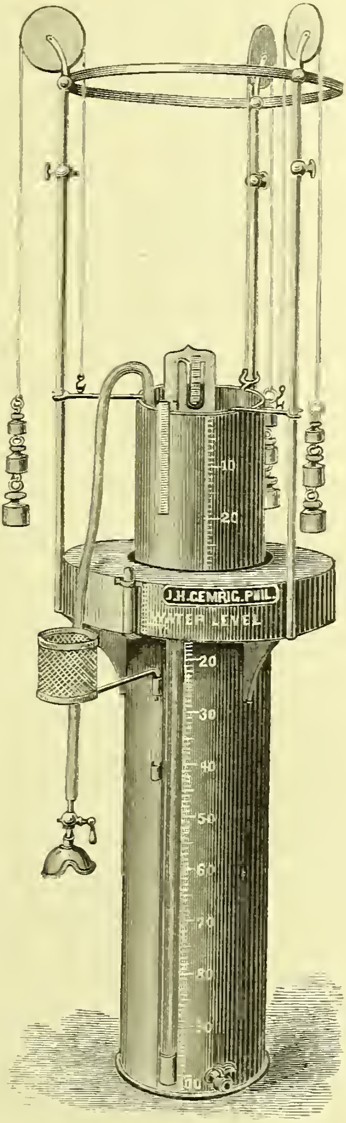
(3) An alternate increase and diminution of intra-thoracic pressure by combining these means.

The combination most frequently utilized is inspiration of compressed air and expiration into rarefied air.

The first apparatus for the application of pulmonary gymnastics was invented by Broesicke, of Berlin, in 1857, but Hauke, of Vienna, in 1870 contributed the first portable apparatus. The number of different forms upon the market is now very large.

One of the best known is that of Waldenburg (Fig. 5). It is constructed on the principle of the gasometer, and furnishes both compressed and rarefied air, but does not permit the alternate use of them. Cube has combined two gasometers, one giving compressed, the other rarefied air, and Weil, with the same end in view, has joined two Waldenburg apparatuses. The apparatus of Schnitzler is only a modification of that of Waldenburg.

Fig. 5.



Waldenburg's Gasometer.

The double ventilator of Geigel and Mayr is constructed on the principle of a wheel, and supplies both forms of air. It is considered in Germany the most practical apparatus.

[The best compressed-air apparatus that we know of used in America is that devised by S. Solis-Cohen (Fig. 6), which he describes as follows:

The air-chamber is 8 inches in diameter and 24 inches high. The water-chamber is pierced at the level of the base of the overflow tank (7 inches from the top) with a row of perforations, allowing the water to escape into the tank under pressure of air in the air-cylinder. A glass tube connected with the tank shows the level of the water therein, and by means of a scale painted on the outer surface of the tank acts likewise as a gauge showing the pressure. The air-cylinder carries, 2 inches from its open base, two shelves, one on each side, on which are placed ballast-weights for the purpose of lowering the centre of gravity and thus maintaining the steadiness of the apparatus. Both shelves and weight are perforated to avoid undue resistance

of water. As the area of the top of the air-chamber is just 50 square inches, atmospheric pressure upon it equals, in round numbers, 750 pounds. With the ballast upon its shelves the cylinder weighs 10 pounds, giving an excess pressure of $\frac{1}{75}$ atmosphere. Weights are furnished in two sizes in the shape of rectangular blocks of iron about $4\frac{1}{2}$ inches by 2 inches surface, and about $\frac{1}{2}$ inch thick and 1 inch thick, respectively. The smaller ones are bored out to weigh $1\frac{1}{4}$ pounds each; the larger ones to weigh $2\frac{1}{2}$ pounds each.

Being placed on top of the air-chamber in successive pairs (one on each side, to preserve balance), they bring the pressure up to any desired amount not exceeding plus $\frac{1}{30}$ atmosphere. Thus:

Cylinder and bottom weights $= + \frac{1}{75}$ atmosphere.

$2\frac{1}{2}$ pounds (2 small weights) additional $= 12\frac{1}{2}$ pounds $+ \frac{1}{60}$ atmosphere.

$2\frac{1}{2}$ pounds (2 small weights) additional $= 15$ pounds $+ \frac{1}{50}$ atmosphere.

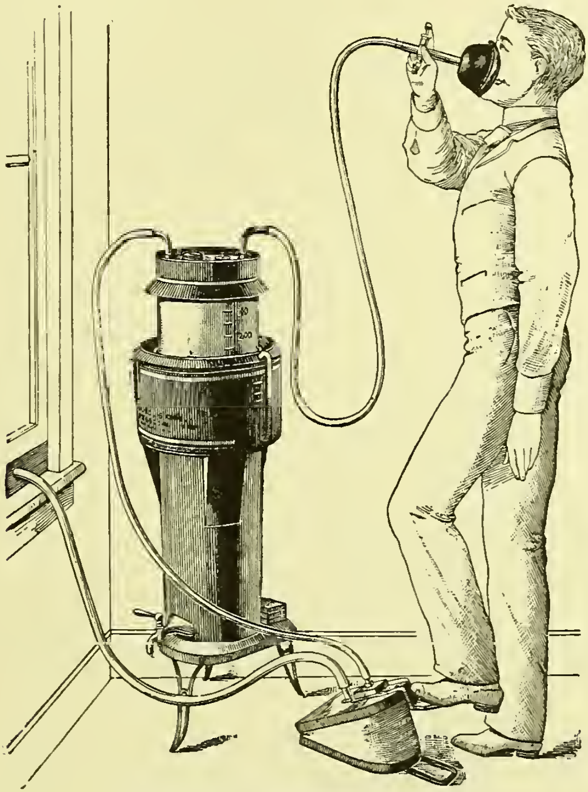
$3\frac{3}{4}$ pounds (1 small weight and 1 large weight) additional $= 18\frac{3}{4}$ pounds $+ \frac{1}{40}$ atmosphere.

$6\frac{1}{4}$ pounds (1 small weight and 2 large weights) additional $= 25$ pounds $+ \frac{1}{30}$ atmosphere.

The air-cylinder is furnished with two goose-necks (Fig. 7), one (8) for the attachment of the tube (6, 7) from the bellows, conveying compressed air; the other (9) for attachment of the tube (10, 11) connected with the stopcock (12, 13) and face-mask (14) or mouth-piece, through which the patient inhales. A perforation 2 inches in diameter is fitted with a screw-cap carrying a hook on which may be placed a sponge saturated with any volatile medicament (*e. g.*, terebene) that may be desired. The cap likewise contains a smaller perforation, into which a manometer may be fitted. When the gauge is not in use this is closed with a rubber plug. Still another perforation in the top of the air-chamber is fitted with a valve that permits escape of air should too much be sent over from the bellows. This valve, which is superior to my own arrangement for the same purpose, is the ingenious device of Mr. F. Metzger, of Philadelphia, who now makes the apparatus in every respect according to my instructions, and who has devoted much time and care to the details of construction in order to secure both strength and lightness. The escape-valve is composed of two flat plates of brass, the upper perforated, the lower unperforated. They are held in apposition by a spring, and when in apposition no air escapes. The lower plate carries a chain 35

inches long, to which is attached a weight that rests upon the floor of the water-chamber. Should too much air enter the cylinder, lifting it too high, the plates are pulled apart, the air escapes through the perforated plate, and the cylinder falls to the proper level. This obviates any liability to splashing of water, which before this attachment was made would occur if attention were not paid to a line

FIG. 6.



S. Solis-Cohen's Compressed-air Apparatus.

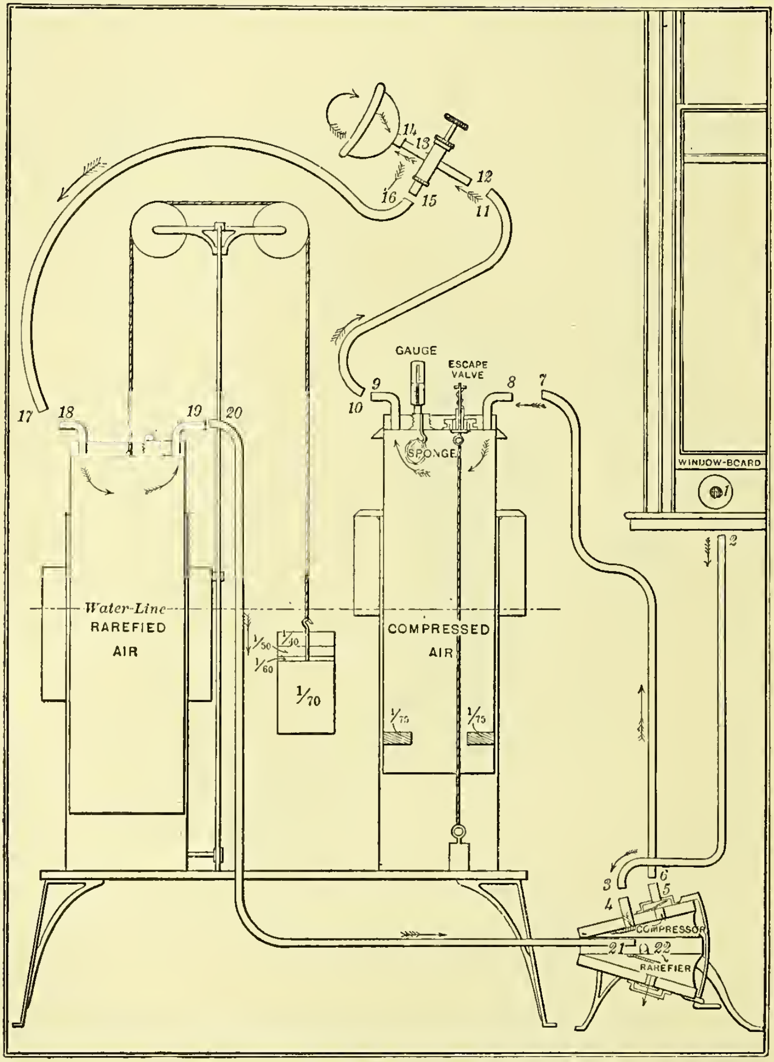
painted on the cylinder to indicate cessation of pumping. By means of the automatic escape-valve we are enabled to introduce a continuously acting pump if desired.

As an additional precaution against splashing the air-chamber and overflow tank are each provided with a deflecting hood about an inch and a half wide and inclined at an angle of 45 degrees.

The second gasometer is for expiration into rarefied air. The connection with the bellows is reversed, so that the latter takes air from

the gasometer and delivers it into the room or the street, and the air-chamber is suspended from a small pulley and counter-poised with weights varied according to the desired negative pressure. The

FIG. 7.



Sectional Diagram of S. Solis-Cohen's Apparatus for Pneumotherapy.

mechanical arrangement of pulleys and weights, the device for adjusting the weights, the lowering of the outer water-tank (now a

reservoir, and not for overflow), etc., are so obvious and so easily understood by looking at the figure ("Rarefied Air," Fig. 7) that a description in detail is unnecessary. Mr. Metzger has used a wire rope in preference to one of hemp. The combination of the two gasometers into one instrument is effected by means of a bellows which at the same stroke compresses air for delivery into one cylinder and rarefies air in order to exhaust the other cylinder. It is in reality two bellows mounted back to back on the same frame. The downward stroke of the lever compresses the upper bellows and expands the lower one. The recoil of the spring in the upper bellows expands that one and compresses the other. There is no communication between the two bellows. By means of a tube (2, 3) passing out of a window-board (1), the external opening being protected with wire gauze, the supply of air for inhalation is drawn from out of doors.

When both instruments are used together, being brought into communication through the lungs of a patient by means of a double stopcock connected with a face-mask or mouth-piece, the route for the air is as follows:

(*a*) From the street, (*b*) through the upper bellows, (*c*) to the compression gasometer, (*d*) thence to the lungs, (*e*) from the lungs, (*f*) through the rarefaction gasometer, (*g*) to the lower bellows, (*h*) which expels it into the room or into the street.

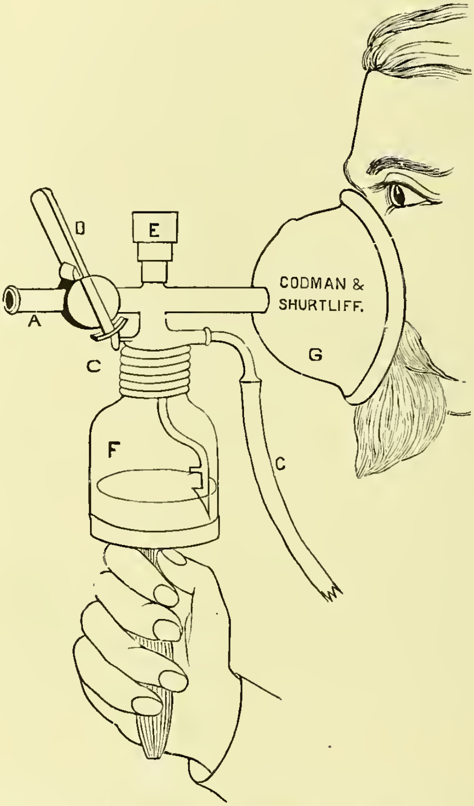
The compression and rarefaction are virtually made in the respective bellows. The gasometers act to a certain extent as reservoirs, but chiefly as intermediate regulating chambers, rising and falling to maintain a constant pressure in exact accordance with the weight placed upon them, and independent of the volume of air inhaled or exhaled. Their available capacity is a little more than 800 cubic inches.

For purposes of observation, sufficiently accurate for clinical comparisons, though not for physiologic data, the air-chambers carry a scale of cubic inches, enabling us to see the approximate volume of air inhaled or exhaled at each respiration. Apparatus for warming, chilling, drying, moistening, or medicating the air to be inhaled may be interposed at any desired point between the window and the patient. The most convenient method of medicating the air is by means of the sponge, as described. A variety of other methods are applicable. Thus a volatile medicament may be placed in or on the water contained in a Wolff bottle, through which the air is passed; or the spray from Oliver's vaporizer, may be thrown into

the inspiratory current by some such device as that represented in Fig. 8.

With the two gasometers described, the double bellows, and a pair of resistance valves, we are able to obtain the mechanical satisfaction

Fig. 8.



S. Solis-Cohen's Apparatus for Medication of Compressed Air by Spray from Oliver's Nebulizer.

F. Nebulizer containing medicinal solution; E, expiration valve; D, lever admitting air and turning on spray; A, attachment for compressed air (low pressure); c, attachment for compressed air (high pressure for spray); G, face-mask.

of all the conditions required for any of the following therapeutic expedients:

Inhalation of—	1.	Compressed	air with	exhalation	into	atmosphere.
"	2.	"	"	"	"	rarefied air.
"	3.	"	"	"	"	compressed air.
"	4.	Rarefied	"	"	"	atmosphere.
"	5.	"	"	"	"	rarefied air.
"	6.	"	"	"	"	compressed air.
"	7.	Atmosphere with		"	"	rarefied air.
"	8.	"	"	"	"	compressed air.]

Inspiration of Compressed Air. The inspiration of compressed air produces a sense of fulness in the chest, it facilitates the entrance of air into the lungs, and leads to an increase in the size of the thorax. According to Waldenburg, the enlargement of the chest amounts, even after a few inspirations, to nearly $3\frac{1}{2}$ cm. Expiration is also made easier, except when, by an exaggerated pressure, the lung is deprived of some of its elasticity.

The vital capacity of the lungs is increased from the beginning of the treatment; at first the increase is transitory, but after several hours it becomes permanent. The forces of expiration and inspiration are equally augmented. The increment of the vital capacity in cases of disease varies from 100 c.cm. to a litre at the end of several days' treatment.

In cases of very feeble expiration this will be found to increase more markedly than inspiration; but when the elasticity of the lungs is not strained the two forces ought to augment in equal ratio. It is probable that the development of the respiratory muscles is a factor in the production of these results, and that they cannot, therefore, be entirely attributed to an anatomical change in the lungs.

In the aged, in whom the costal cartilages are ossified, no appreciable modification is produced, either in the play of the respiratory movements or in the development of the thorax.

Gréhant, Ducrocq, Drosdoff, Waldenburg, Botschetschkaroff, Basch, and others who have studied the question, find that the increase in intra-thoracic pressure opposes an obstacle to the circulation, especially to the diastole of the heart, while the systole is favored by it. The result is a stasis in the veins and a fall of pressure in the aorta. But these effects are only noticeable during inspiration, and disappear during expiration.

The pulse, studied sphygmographically by Riegel and Frank, Waldenburg, Sommerbrodt, and Schreiber, is strong and full at the beginning of inspiration; later, as the pulmonary stasis diminishes and the arterial tension falls, it yields a higher and well-marked dicrotic tracing. The circulatory changes are, however, transient, although some authors have seen them persist for one-half to one hour.

Expiration into rarefied air produces mechanical phenomena exactly the reverse of those caused by inspiration of compressed air.

The diminution of intra-thoracic pressure brings about a compression of the thoracic walls, of which the patient becomes conscious

when the rarefaction amounts to one-thirtieth atmosphere. Extension is more complete and the volume of air given off, as measured by the spirometer, is augmented. This increase takes place at the expense of the residual air; it may reach a litre with a rarefaction of one-fiftieth to one-sixtieth atmosphere (15 : 13 mm. of mercury)—an interesting fact that seems to indicate that the quantity of residual air is greater than is generally believed. Waldenburg has observed emphysematous patients expiring 5 or 6 litres of air (under the influence of a rarefaction of one-fortieth to one-sixtieth atmosphere) when their normal respiratory capacity did not exceed 2 to 3 litres.

The compression of the thorax evidences itself in a diminution of the circumference of the chest 2 or 3 cm.; at the same time, under the influence of forced expiration, the respiratory muscles acquire greater play, the diaphragm rises higher, the excursions of the chest become more extensive, and soon the inspiration is also increased. The result is an augmentation of the vital capacity of the lungs.

The reduction in intra-thoracic pressure modifies the circulation, the phenomena produced being the reverse of those noted in the case of compressed air; the systole of the heart is impeded, while the diastole is favored; there is a tendency to the emptying of the veins and the filling of the arteries.

As the lung fills with blood the right auricle becomes distended, then, in turn, the left auricle and left ventricle; the pressure in the aorta rises, the jugular veins collapse and empty themselves. The study of these phenomena, made upon animals with the hemodynamometer, on man with the sphygmograph, have not yielded very decisive results. Nor can the results in animals be properly compared with those obtained in man.

It is important to note, from a practical standpoint, that by taking slow and prolonged inspirations the influences to which the circulation is subjected at the moment of expiration into rarefied air are weakened. By observing this practical point a marked action can be obtained upon the lungs, while that upon the heart is attenuated. The value of this is considerable in all cases where any exaggerated interference with the latter organ is to be dreaded.

The inspiration of compressed air and the expiration into rarefied air do not produce mechanical effects alone. Biedert holds that as the air strikes the respiratory passages with more or less force it provokes a certain degree of irritation.

The pressure to which the pulmonary tissue is exposed, as well as

the alternate repletion and depletion of the vessels, is an additional cause of irritation. It follows, therefore, that the treatment should always be medically supervised.

The researches of Speck seem to show that the method also produces a chemical action. The increase in the pulmonary aëration leads to an augmentation of the oxygen absorbed and of the carbonic dioxide eliminated. As far as the superoxidation of the blood is concerned, inspiration of compressed air acts in the same manner as respiration in the pneumatic chamber. The expiration into a rarefied atmosphere withdraws a considerable quantity of residual air, rich in CO_2, and thus brings about a decarbonization of the blood, and consequently an antidyspnœic effect.

Speck expresses the results that can be obtained by the following figures: Increase in air respired, 1 : 1.62; increase in oxygen absorbed, 1 : 1.14; increase in carbonic dioxide eliminated, 1 : 1.30. The same author has also demonstrated that the increased consumption of oxygen and elimination of carbon dioxide do not necessarily augment intra-organic oxidation.

Although all these effects are ultimately mechanical, depending upon the physical laws of the diffusion of gases, nevertheless the improved respiration which supervenes when the treatment is persisted in brings about an altered state which impresses the entire organism and stimulates the nutritive processes. Decisive researches are still wanting in regard to the question of nutritive effects.

As already stated, the combination most frequently resorted to is the inspiration of compressed air and the expiration into rarefied air. Two methods are in vogue—in the one, known as the *intermittent method*, the patient makes a series of inspirations of compressed air, the expiration being into ordinary atmosphere; then follows a series of expirations into rarefied air, inspiration taking place in the normal atmosphere.

The *alternating method* consists of an inspiration of compressed air followed by an expiration into rarefied air.

In these diverse combinations the mechanical effects do not counterbalance themselves, they alternate.

The lungs fill and empty themselves more completely, and pulmonary aëration is rendered as energetic as possible. It is this form of pulmonary gymnastics that exercises the most marked effect upon dyspnœa.

Furthermore, while the one factor in the method produces hyper-

æmia of the lung, the other leads to anæmia. There is, therefore, not a continuous action, but an alternating one, which stimulates the pulmonary circulation.

Under these circumstances there need be but little fear of hemorrhages, as the effects upon the heart and circulation are less pronounced than in the case where only one of these practices is employed.

Therapeutic Application. The technique is quite simple. Various forms of masks and mouthpieces have been devised, but the best is a sort of trumpet, which is applied to the mouth. The patients should be instructed to breathe slowly and deeply; if desirable, the nostrils may be occluded.

In the beginning of the treatment the applications should be brief and should consist of a series of inspirations of compressed air, followed by expiration into ordinary air. Later, recourse may be had to the alternating method.

The duration of the treatment is variable; it can be prolonged without inconvenience. The spirometer and pneumotometer enable us to determine the exact results achieved.

In special cases the inspired air may be charged with medicinal substances; if necessary, its temperature may be modified and it may be impregnated with watery vapor.

As inspiration of compressed air diminishes the afflux of blood to the lungs, it may be considered as an antiphlogistic measure. It is chiefly indicated in the cases in a which predisposition to phthisis exists, and even in those in which the disease is already established. It favors the expansion of the lung after the subsidence of a pleurisy, and hastens the absorption of exudates. In addition, it is capable of causing the disappearance of atelectasis in bronchitis, and re-establishing the permeability of contracted and compressed bronchi; it also facilitates expectoration.

Expiration into rarefied air, since it determines a better evacuation of the accumulated air from the lung, is especially applicable in emphysema and in chronic bronchitis. Hence the alternating method is most useful.

All these methods of pulmonary gymnastics in general render most excellent service in cases in which the thorax is contracted and the respiratory muscles are enfeebled, conditions seen in persons of the "phthisical tendencies." Under these circumstances the treatment is eminently prophylactic.

It is also recommended in chlorosis and in other anæmias, and in dilatation of the heart. The results in these diseases are more doubtful.

Inspiration of compressed air is contraindicated in arterial atheroma, in the apoplectic habit, and in dropsy and venous stasis.

Cardiac weakness, the tendency to hæmoptysis, dilatation of the bronchi, the existence of acute inflammation of the respiratory apparatus, contraindicate expiration into rarefied air.

PART II.

CLIMATE.

WE come now to a consideration of a complex natural agent—climate—a potent resort in the treatment of disease.

By climate we understand the complexus of meteorological conditions to which a terrestrial place is subjected during the course of a year. From the medical standpoint climate is considered in its relations to and influence upon the life of organized beings.

Hygiene studies climate in its constituent elements and investigates the effects which it produces on the individual or the race, the causation of disease, and on mortality.

Therapeutics concerns itself with the influences which a change of climate has upon disease. So important are these influences that Michel Levy has uttered the dictum: "Change of climate is equivalent to rebirth."

When life is menaced by a dangerous malady, or is liable to be so menaced by the later development of an incipient disease, the profound influence for good which a change of climate has upon the health should always be considered. Any action taken upon this consideration should be deliberate and should be founded upon an intimate knowledge of the climate selected, particularly of its therapeutic influence.

A few points, not directly germane to such knowledge, are of sufficient importance to warrant a brief consideration.

The transition from one climate to another should not be abrupt. It is important not to transport a patient from the cold frigid directly to the hot torrid zone. The facilities of the journey or of the voyage should also receive attention.

The place selected should possess satisfactory conditions, and should offer sufficient resources for the personal comfort of the patient. In certain cases a change of climate becomes therapeutically useful and enables the patient to return to his native country. This occurs in

Europeans who, after having become ill in the tropical or torrid zone, return to their homes to recuperate.

It is not necessary for our purposes to study deeply the subjects of meteorology and hygiene; yet it is incumbent upon us to take at least a rapid review of the principal meteorological conditions which determine climate. Of these the first is *latitude.*

The latitude of a place is important on account of its relations to the mean annual temperature.

The distribution of this temperature would always be indicated by the parallels of latitude, if the earth were an elliptoid with a regular revolution; if it did not possess mountains and valleys; if its surface were everywhere uniform; and if the atmosphere were in all places identical in composition. The differences between different parallels of latitude would then depend entirely upon the relative duration of day and night and upon the inclination of the solar rays.

But it is not so; many causes contribute to produce variations in temperature, even in places on the same parallel of latitude. Yet we may divide the surface of the earth into five geographic zones, each of which presents certain general and distinctive features.

The torrid zone comprised between the latitudes of 23° 28′ north and south of the equator is characterized by a uniform and very high temperature.

The two temperate zones extend from their respective tropics to polar circles, namely, from the latitude of 23° 28′ to that of 66° 52′. As we recede from the tropics the temperature grows progressively more variable within the limits of a year, and the mean temperature becomes lower.

It is the northern temperate zone that alone interests us. The majority of health resorts to which reference will be made are situate between the parallels of 30° and 45° north latitude. As we advance northward this zone—the temperate zone—falls approximately one degree for every distance of 185 kilometres; but this is not an absolute rule.

The heat lost by the earth depends upon the length of the nights. When these are short a part of the heat gained during the day is retained. It is on this account that the hottest days are not those of the summer solstice, but those which succeed it, in July and August. Inversely, the coldest period in winter is that following the winter solstice.

Lines joining points that have the same mean annual temperature

are known as *isothermal lines*, and were first constructed by Humboldt. As many conditions influence the temperature, these lines deviate more or less from the parallels of latitude.

It is also important to consider the mean monthly temperature, charts of which, comprising the principal climatic stations, have been constructed by several authors.

In our hemisphere the isothermal lines of summer and winter vary sensibly from the annual isothermal lines. It is likewise important to inquire into the diurnal and nocturnal variations of temperature at each health station.

For several reasons, of which mention will be made below, the islands and the western coast of Europe are warmer in winter and cooler in summer than the annual isothermal lines would seem to indicate.

Altitude. The latitude being the same, the altitude plays a considerable part in determining the characters of the climate. It not only influences the temperature, but all the other meteorological factors which together constitute climate. Hence the majority of authors have made altitude a basis of division of climates. Mountainous countries offer divers climates superimposed upon each other.

The effect of altitude upon the temperature is not an absolutely regular one; but it is generally estimated that in the temperate zone an elevation of 150 to 180 metres corresponds to a fall of one degree in the temperature. The principal causes of the diminution of the temperature are the rarefaction of the air and the consequent decrease in its power of absorbing heat, the insulation of the soil at high altitudes by snow and ice, the great diathermanous qualities of the atmosphere, and, finally, the diminution in barometric pressure, leading to a great expansion of the heated air which rises from the ground.

The other important influences of altitude are those which it exerts upon the gaseous composition of the atmosphere, upon its purity, upon the intensity of light, and upon the heating of bodies by solar radiation.

Geographical Selection. After latitude and altitude the condition having the greatest influence upon the climate of a place is its geographical position. In this respect it is of especial interest to consider proximity to or remoteness from the sea-coast.

The sea absorbs and emits heat less readily than the land. It possesses, however, a greater specific heat, so that for the same quan-

tity of heat absorbed or emitted it suffers a smaller variation in temperature. Finally, a part of the heat which the sea absorbs is expended in the formation of vapor. From these data it follows that the great bodies of water become heated and cooled more slowly than land. To these causes of the reduction in the temperature variations in the neighborhood of the sea, we should also add the influence of the watery vapor, and especially of the clouds. These masses of vapor temper the heat of the sun during the day and diminish the loss of heat by radiation during the night.

It is evident, therefore, that for any given latitude, propinquity to the coast renders the climate distinctly less variable than it is in the interior. Two classes of climate, a maritime and a continental, may be distinguished. The first is generally temperate; the second may be hot, even in places having the same latitude as the place on the coast.

As an example of the influence of geographic position, let us take Cherbourg, Paris, and Vienna, three cities situated approximately on the same parallel of latitude. The difference between the mean summer and winter temperature is 10° for the first, 15° for the second, and 20° for the third.

It is for the reason stated that insular climates are the most constant. On some of the tropical islands the difference between the mean summer and winter temperature does not exceed two or three degrees.

The large continents present marked contrasts; heat and cold are more intense there, and the changes of temperature are great.

Influence of Wind. The topic of geographical situation may well be followed by a reference to the influence which atmospheric and marine currents exercise upon climate.

The most important aërial currents are the so-called trade-winds, which flow with a remarkable constancy throughout the year in the vicinity of the equator, but also make their influence felt at remote distances. According to the explanation which Halley has given of the origin of these winds, the existence of upper anti-trade winds passing from the equator to the poles must be admitted. The masses of air composing these anti-trade winds arrive in the temperate zones with a velocity of rotation which is greater than exists in the atmosphere of these regions. This condition gives rise, theoretically, in the higher parts of the atmosphere, to a southwest wind in the northern, and a northwest wind in the southern, hemisphere.

These winds exercise an appreciable influence upon the climate of western Europe (the northern portion of the Atlantic Ocean). They are the cause of the predominance of northwesterly winds in western Europe (England, the Netherlands, and France).

Before arriving on the European continent they pass over a part of the Atlantic Ocean traversed by the Gulf stream. This current has a decisive influence upon the climate of the coasts which it bathes. It originates in the Gulf of Mexico and passes in a northeasterly direction toward Europe, making itself felt along the coast of Norway as far as the North Cape.

The mechanism of this marine current is the same as that of the trade and anti-trade winds. It represents in the Atlantic Ocean the upper atmospheric current, which carries the warm air of the equator toward the poles.

The winds thus borrow from the surface of the sea moisture and warmth and carry these to distant regions. The exceptionally favorable climate which the countries of western Europe enjoy is due, as will be seen, to two causes—a current of temperate and moist air, and a current of tepid water, both derived from the equatorial regions.

Diverse local conditions, not all thoroughly understood, also give rise to certain aërial currents, of which the land and sea breezes are the most constant.

On the sea-coast a wind begins to blow from the sea to the land soon after sunrise; at first slight, it gradually grows in strength, later diminishing, until it ceases in the evening. A reverse movement now sets in, and the wind rising from the land blows toward the sea, gently at first, but growing in strength until midnight; toward morning it gradually dies away. The mechanism of these movements is simple. During the day the warm air rises from the earth into the higher regions of the atmosphere, and the denser air of the surface of the sea enters to take its place. The opposite condition obtains at night; the air of the land now becomes denser and is carried out to the sea.

Mountain breezes are a species of local winds which are very variable in regard to their violence and other characters, but their origin is nearly always the same. During the day the atmosphere of the valley and lower regions becomes heated, and, rising along the mountain-side, constitutes the valley or morning breeze. This upward movement is favored by a sort of aspiration—the lighter air

ascending to higher levels is replaced by the heavier air of the lower regions. After the setting of the sun the air on the mountain-summits becomes cooled, and in its descent to the valley creates the mountain or evening breeze. It thus happens not infrequently that the nights in the valleys are cooler than on the declivities of the mountains.

A few special winds, peculiar to certain countries, merit brief mention. The simoon is a hot, dry wind, coming from the desert of Arabia. It rarely blows in any of the health-resorts. The sirocco is the hot wind of the Sahara. It strikes especially Sicily and Italy, but makes itself sometimes felt at the stations on the Riviera, where it appears as a southeast wind. In passing over the Mediterranean it becomes charged with humidity, and therefore carries rain. In Switzerland the most formidable of all the winds is one which prevails principally in the northeastern cantons. It is generally a hot and relatively dry wind, but its characters vary according to the different places over which it passes. Other winds are the bora, of the Adriatic Islands, and the mistral, which visits the French Mediterranean shore.

The last condition, the influence of which upon climate needs to be investigated, is the configuration and composition of the soil. Other things being equal, the peculiarities of the soil may often produce such a marked modification of the climate as to cause notable differences in the climatic character of places in close proximity to each other.

On the great plains the temperature rises very high during the day, to fall very low during the night. The interesting observations of Martins have shown that the cooling of the air at night diminished as we rise above the level of the soil up to a certain height, particularly when the nights are serene. The increase of temperature is rapid at first, then more slow. It is for this reason that the ground of plains and low places is covered with fog, and that the upper floors of houses and hospitals are drier and healthier than the ground-floor.

Along the borders of rivers and lakes a height of 90 feet, or even less, above the level of the water will afford shelter from the fogs which hover over their surface. This should be remembered in constructing habitations in such places.

In hilly regions the oscillations of temperature are less great than in the spreading plains, but the heating of the soil by the solar rays takes place irregularly; local winds are generated, and are accom-

panied by more or less abrupt changes in the temperature and the humidity. Mountain ranges also produce changes in the meteorologic conditions of the surrounding country. These changes vary with the height of the summits, the extent and trend of the range, and the nature and abundance of the vegetation. Mountain-chains may serve as barriers to cold and to hot winds, and may, consequently, cause an elevation or depression of the annual temperature of the contiguous regions.

They exert, moreover, an influence upon the winds themselves, causing a condensation of the watery vapor when they, the winds, are heavily charged with humidity. They may thus render the climate of one place dry and of another more moist.

The local condition, being so very variable, should be specially studied for each place.

In regard to places situated directly on a mountain, the most important point for investigation is whether they are upon the sunny or the shady side. In the northern hemisphere the southwest side is generally the hottest, and the northeast the coldest. The west side is a little warmer than the east.

The prevailing direction of the wind should also be inquired into, for this is of even greater importance than the exposure of the place. Indeed, it is upon this that the conditions of humidity especially depend. In Europe the southwest declivities are generally more moist than the southeast, although they receive more heat.

The surface of the soil has an important influence upon the temperature and humidity of the lower strata of the atmosphere. The experiments of Frankland have revealed certain relations between the nature of the soil and the solar heat.

Snow offers the strongest reflecting surface; after it, in a descending order, may be named light-colored soil, dried grass, gray rocks, and green grass.

The absorbing power of the soil is in inverse ratio to its radiating power. The lighter the color of the surface the greater is the solar heat and the cooler is the atmosphere. A dark soil is associated with a warm atmosphere, while the radiant heat is proportionately less great.

The power of absorbing moisture is still more variable according to the nature of the soil than the heat-absorbing power. Elliott states that turf absorbs more than twice its weight of water, dry clay its own weight, dry garden soil half its weight, sand a little more

than a third. This explains why sand dries so quickly and turf so slowly.

Buchan has proved that drainage influences to a marked degree the temperature of the soil. He found that it elevates the temperature of arable land approximately one degree. Cold penetrates more rapidly through undrained than through drained land. Irrigated soil loses its heat less readily than soil which is not irrigated; such a soil has also more constant temperature. These facts may elucidate the diminution of phthisis, which Bowditch, Buchan, and others have observed to follow the establishment of drainage.

The presence or absence of vegetation, and the nature of this vegetation, modify in a marked degree the factors of climate.

The vegetation which covers the earth hinders more or less effectually the solar rays from reaching the surface of the soil, and thus moderates the temperature in a variable degree. On the other hand, plants themselves, by reason of the constant evaporation from them, tend to modify the temperature.

The effects produced by the vegetation of a region varies with the character which this vegetation generally assumes, namely, whether it be forest, meadow, or turf.

We owe to Fautral and to Erlenmeyer the greater part of the knowledge we possess concerning the influence of forests.

The soil of forests has a lower temperature than that of prairies to a depth of one yard, the difference being more marked in summer than in winter. The temperature of the air of forests is also lower than that of the prairie. We all have found during the noonday heat delightful coolness in the forest shade. The temperature-variations are less abrupt in forests than on plains, and the climate is more constant.

The days are cooler and the nights warmer, but the difference between the maximum and minimum temperature is less marked. The humidity is always greater than it is on the plain, exceeding that of the latter by nearly 10° in July, and 3° to 7° in January. Rain is therefore more abundant in forest regions than in those denuded of their trees. Lastly, forests may arrest winds, and thus exert an appreciable influence at distances more or less great. Regarding the climate of cultivated plains, it is well to know that it is never so warm as that of regions from which vegetation is absent. H. Weber has noted a difference of 11° to 17° between the soil of a barren district and that of an adjoining plain.

Peat or turf lands and swamps are characterized by a high degree of humidity of the soil and air, and by a relatively low annual temperature. Fogs are not common. The air in these marshy districts frequently harbors the poison of malaria, which may be wafted to distant regions according to the direction of the wind and the configuration of the surface.

From another point of view, the vegetation of a place furnishes a valuable indication of its climate, and we may, indeed, say, with Ch. Martins, that plants are living thermometers; or, with Fonssagrives, that they are truly climatometers.

The investigation of the flora of a country is, therefore, an important study.

From the therapeutic standpoint, the climatical and astronomical seasons do not exactly coincide. Summer comprises the months of June, July, and August, and stations visited during these months are known as summer stations. December, January, and February are the winter months, and stations at which they are passed are known as winter stations. The other seasons correspond to the intermediate months.

Of the various elements or factors of climate the first to be considered is the constitution of the atmosphere, which is obviously of the greatest importance, since the air we inspire is the very principle of life, and upon its qualities depend, in a large measure, health and disease. Its importance attracted the attention of the great physicians of antiquity, notably of Hippocrates.

Concerning the subject of chemical constitution we find that the subject still presents many obscurities. The pressure being equal, the proportion of the gaseous principles is almost constant. The slight variations in the quantity of oxygen have no visible influence upon health.

The quantity of carbonic dioxide contained in the air is, as a rule, very small, but may at times be augmented without becoming harmful. This increase, however, deserves attention, since it is correlated with the presence in the air of heterogeneous principles that may be noxious.

Another constituent of the air is ozone, which chemists regard as a combination of oxygen with itself (an allotropic form of oxygen). The presence of ozone bears some relation to the electric phenomena of which the atmosphere is at times the scene, for frictional (static) electricity, to which that of the air belongs, ozonizes the atmosphere.

Although the proportion of ozone is normally very small, 1 in 10,000 as a maximum, there is nevertheless a certain importance attributed to it. Not that this form of oxygen is capable, in such small amounts, of influencing the organism to any appreciable extent, but the conditions in which an increase is noted seem to be favorable to good hygiene. Thus it is not present where putrefaction prevails, nor in hospitals. In the interior of cities the quantity of ozone is less than in the country; more is found in the air along the seacoast than further inward, and likewise more in the mountain atmosphere than in that of the plains. The only sensible effect of small quantities of ozone consists in an increased tendency to sleep.

The humidity of the atmosphere is also of great importance to the study of effects of climate.

Beside the gases proper the atmosphere always contains a certain quantity of watery vapor, and it is this constituent which, from the climatic standpoint, is the most important.

The proportion of watery vapor contained in a given volume of air depends upon the temperature. Two forms of humidity, an absolute and a relative, must be distinguished. By the first is implied the quantity of vapor contained in a certain volume of air; the second indicates the relation between the quantity of vapor and that which the air would contain if it were saturated. When we speak of dry air or moist air we refer to the fact that the relative humidity is respectively low or high. The absolute humidity varies with the seasons, and obeys, up to a certain point, the fluctuations of temperature. It is more elevated in summer than in winter. The variations in relative humidity follow almost a directly opposite course, and for our purpose the greater interest centres in them.

According to Humboldt, the lowest degree of relative humidity is 23 per cent. The air is very dry when the relative humidity is under 35 per cent., moderately dry when it rises to from 55 or 75 per cent., moderately humid when it is from 75 to 90 per cent., very humid at 90 to 100 per cent.

The humidity varies not only according to the seasons, but also according to the nature of the winds, particularly when these come from the sea, and according to the different periods of the day. It is generally highest at sunrise, the minimum being reached during the early afternoon hours.

Closely related to atmospheric humidity are several interesting meteorological phenomena, such as fog, clouds, and rain. Fog and

clouds moderate the variations of temperature of a region, and consequently play a part in the determination of the climate.

The influence of rain must be considered from several points of view. The quantity which falls during a year is extremely variable. It is estimated by means of pluviometers (rain-gauges). From nothing on the Sahara it rises to nearly twelve yards on the south-eastern declivity of the Himalaya Mountains.

In medical climatology account should be taken of the number of rainy days in a year and in each month. There is no relation between this number and the quantity of rain. It is also important to note the hours during which rain falls, for upon this fact depends the length of time the patient can remain in the open air.

In the mountains the rain is replaced by snow, which, happily, quite often falls only toward evening or at night.

Despite the deprivation of water, represented by the snow or the rain, the atmospheric air preserves its humidity.

The degree of evaporating power of the atmosphere depends upon a number of conditions, such as the temperature, the relative humidity, the density, and the velocity of the wind. This power possesses considerable physiological importance, since it regulates the cutaneous evaporation, and, in part, the loss of heat from the surface of the body.

The atmospheric humidity is thus as essential to life as oxygen itself. It determines the distribution of heat on the surface of the earth, and also prevents the warm air from rising too rapidly into the higher strata of the atmosphere and being thus lost to us. The vapor of water is practically opaque; it prevents the radiation of heat. This explains why the condensation of vapor consequent upon the cooling of the soil constitutes a means of protection. Humid climates for this reason possess the advantage that the thermic variations between the day and night are but slight, and that the temperature is more constant. The excess of humidity is, however, in some respects inconvenient, for it intercepts the light and heat and produces a depressing effect upon the system.

The action of humidity on the human body is very noticeable, but difficult to define on account of its complexity. Thus the degree of absolute humidity is an important factor as regards the respiratory functions. The dryer the air the more moisture it absorbs in its passage through the air-passages. Hence the diminution of the expectoration in a dry climate.

The relative humidity produces its effects especially upon the func-

tions of the skin. In a dry and warm air cutaneous evaporation is very active, while in a cold and dry atmosphere it is the pulmonary evaporation which is especially stimulated. Warm, moist air, particularly in the absence of wind, impedes perspiration and gives rise to conditions in which variations of temperature produce those diseases attributed to "cold." Moreover, the appetite and the nutritive functions are depressed, and even healthy individuals experience a disinclination for work. A certain class of patients are comfortable, temporarily at least, in a moist and warm atmosphere, because it diminishes the irritation of the respiratory mucous membrane.

On the other hand, those same conditions conduce to the development of intestinal diseases, especially diarrhœa, and are eminently favorable to the growth of micro-organisms. In any case there are certain warm, moist climates where pulmonary phthisis not rarely pursues a rapid course.

A cold, dry climate is also not free from inconveniences. In diminishing the cutaneous evaporation and increasing the loss of heat it predisposes to catarrhal, rheumatic, and renal affections.

A large rainfall does not constitute such an unfavorable condition as might at first appear. It clears the atmosphere of dust, facilitates its renewal, and diminishes the relative humidity.

Naturally, when the rainfall is too continuous it becomes harmful, since it then interferes with outdoor exercise. The disadvantages of rain are more marked when the soil is so constituted as to become easily impregnated with water.

The effects of snow are rather good than otherwise when it is persistent and not exposed to successive thaws. It purifies the atmosphere, renders it more transparent, augments the reflection of solar heat, and prevents heating of the air and the production of winds, which are the consequences thereof.

In addition to the factors governing climate which we have just discussed there are other influences to be considered. The composition of the air may rarely be modified by the presence of foreign principles. Of these, ammonia is one of the most common; traces are nearly always present; if present in certain proportions, it exerts some influence, but less upon animals than upon plants. Along the borders of the sea the atmosphere contains saline particles, which are absorbed by the respiratory passages, and also deposited on the external surface, and it is to them that the tonic effects of sea-air are in part due.

The purity of the air should always receive the most profound consideration. As is well known, the atmosphere nearly always holds a variable proportion of solid particles, organic and mineral.

Of the mineral, silica, lime, and iron are most commonly found. The organic particles comprise seeds, pollen, grains, spores, ova, and micro-organisms. The researches of Ehrenberg, Schwann, and Tyndall have revealed many interesting facts upon this subject, but no experiments have attained such celebrity as those of Pasteur, who first demonstrated, in a striking manner, the difference, as regards the presence of germs, between the air of glacier regions and that of inhabited districts.

By the method of Miguel we are able to determine, with a remarkable degree of exactitude, the number of foreign particles contained in a given volume of air. Many observations made by this author have shown that the number of low organisms in 1 cubic yard varies within wide limits. Thus in the park of Montsouris it oscillated, in 1879, between 33 and 170; whilst at the summit of the Pantheon it was 28. It rose to 750 in Rue de Rivoli, to 5200 in a room of the Rue de Monge, to 6300 in one of the wards of the Hôtel-Dieu, and to 11,000 in the surgical wards of La Pitié.

More recently he has compared specimens of the air of different localities collected at nearly the same time.

He found no bacteria in the neighborhood of the Mer de Glace at an altitude of 2000 metres; there were only 0.8 in the air on the lake of Thun, whilst 760 were counted in the atmosphere in the park of Montsouris, and 5500 in that of the Rue de Rivoli.

Freudenreich also found no schizomycetes at altitudes of 2100 to 3200 metres; but when there were habitations the air even at these heights contained a few micro-organisms. Great purity of the air is, then, one of the important characteristics of mountain climate.

In addition to its chemical composition, note must also be taken of the temperature, the density, and the renewal of the atmosphere.

Having discussed the complex meteorological conditions which determine temperature, we shall now study the effects which the climatic factor temperature exercises upon the organism. The question, however, is not a simple one, for it is evidently difficult to isolate the effects attributable to the temperature of a climate from those produced by the humidity, the light, and the altitude.

The solar heat is to some extent a luminous heat. Indeed, the sun is the principal source of both heat and light for the atmosphere

as well as for the soil. The quantity of caloric and light yielded by the moon, the stars, and the centre of the earth is insignificant.

It is important not to confound radiant or solar heat with the heat which the air acquires by being warmed. Thus on mountains, as has been said, the air is cool (absence of warmth), while the solar heat (radiation) is intense.

Radiant heat warms directly the bodies which it strikes; but its calorific power is very small for the strata of air which it traverses, because gaseous substances, in contra-distinction from watery vapor, are incapable of absorbing the sun's heat; or, in other words, they are diathermous.

The physiological effects of solar heat are as yet not well understood, but it is certain that they are very potent. Other things being equal, the solar heat is more easily borne than that of the air, for the reason that the latter, being charged with watery vapor, suppresses cutaneous evaporation and the cooling of the body, which is dependent upon it.

An individual who is able to perform a laborious task under a solar heat of 120° F., becomes rapidly fatigued in the shade, when the temperature of the air is only 90° to 96° F. On mountains where the sun's heat is very intense, but the air dry and cool, sunstroke is almost never observed; the same is true of the open sea, where, although the solar rays may be very hot, the air is in motion, or, at least, frequently renewed.

The luminous and chemical rays of the sun exercise undoubtedly a direct action upon the molecular movement constituting the nutritive processes of the tissues.

The beneficent effects of sunlight have been praised by all nations. Pliny wrote: *Sol es remediorem maximum.* Among the Italians this dictum is current: "All diseases develop in the shade and are cured in the sunlight." Many interesting facts and experiments corroborate the correctness of these common observations.

Sunlight exerts a powerful chemical action upon vegetation; without it chlorophyll does not develop. Moleschott has shown that under the same conditions of temperature frogs exhale more carbon dioxide in the light than in the darkness. More recently S. Fubini and A. Benedicenti, in studies upon hibernating animals, have found that light increases the respiratory changes, even if the animals are in complete lethargy. The interesting experiments of Edwards also demonstrate the important *rôle* of light in the normal development of animals.

In man light seems to influence the formation of hæmoglobin in a manner analogous to that which regulates the production of chlorophyll in plants.

The deprivation of sunlight conduces to anæmia, while the opposite condition favors the regeneration of the blood. Sunlight also influences the pigmentation of the skin. The chemical effects of the solar rays manifest themselves at the points upon which the rays impinge. The air heated by conduction does not become chemically active.

A clear sky is not without influence upon all the bodily functions, and even, according to Humboldt, upon the sensations. It seems to elevate and to sustain the moral tone; and, finally, the very sunlight which is so wholesome for us is deleterious to our enemies, the pathogenic micro-organisms.

Koch and H. Martin have demonstrated the destructive action of light upon the tubercle bacillus. Other micro-organisms are also affected by sunlight. Diffuse light has the same effect in kind, but less powerful in degree. Is it possible that to these various effects of light the relation which exists between the amount of sunshine and mortality in a district is due? The death-rate is lower the longer the time during which the sun shines.

Whenever it becomes necessary to pass judgment upon the value of a winter resort, the details regarding sunshine should be considered of the greatest importance after the qualities of the air. It is necessary that one day out of every two be sunny, and that the duration of insolation be at the minimum six hours a day.

Nearly all mountain stations are characterized by a great intensity of light and by radiant heat, which, even in Alpine stations, can cause the thermometer to rise in winter to 50° F., so that patients are able to promenade upon the snow-covered walks, with warm clothing and protected by parasols. So great is the direct sun heat that in certain persons a slight degree of nervous excitement is produced. In some instances this peculiar effect of the sunlight is exerted through the eyes.

The abrupt passage from the sun into the shade should be carefully avoided, as it exposes the patient to a considerable degree of cooling.

A hot climate produces effects that vary with the individual. Europeans are often embarrassed by it, especially if they continue to partake of the same foods and the same fermented beverages to which they were accustomed in their native climes.

Parkes attributes to the heat a depressing influence upon nervous activity, the digestive functions, those of respiration, and upon general nutrition.

Natives of Europe are apt to become sick in countries the mean temperature of which exceeds that of their own homes by 11° C.

They become enfeebled and their stock dies out at the end of a few generations, unless they intermarry with the indigenous races. These facts prove how erroneous is the belief that hot climates are suitable for individuals of delicate constitution or those debilitated by chronic disease.

The summer stations of the temperate zone and the winter stations of the tropics offer a moderate temperature of 13° to 21° C. (56° to 70° F.). Robust persons, especially if young, are enfeebled rather than strengthened in such climates. Their appetite diminishes, digestion, respiration, circulation, and oxidation become lessened, the mental faculties are depressed, and the urinary secretion reduced correlatively with a greater activity of the cutaneous functions. Debilitated persons, on the other hand, are stimulated and become more resistant to disease. Heat and sunlight seem to be vital conditions for such individuals; under their influence the nutritive functions are quickened and the body-weight increased.

There are some patients, however, that are benefited by a colder climate, such as prevails during the winter in the stations of the temperate zone. These places are favorable to strong individuals, well clothed and properly nourished, whose digestive functions are satisfactorily performed.

For conditions characterized by a sluggish venous circulation and by intestinal torpor and nutritional disorders in their early stages, such a climate is very advantageous, since it secures a greater activity of the circulation, of the respiration, and of hæmatosis, and an augmentation of physical energy.

Patients who are feeble and sensitive to cold are apt to fall, in such climates, into a state of lethargy and torpor that has been compared to hibernation. The skin, especially of the extremities, becomes blue and cold, the appetite diminishes, the intestinal functions are paralyzed, intellectual and physical energy is depressed.

Atmospheric Pressure. It is important, in climatological studies, to take cognizance of the distribution of atmospheric pressure. It is indicated upon charts by isobaric lines. The predominance of winds and the quantity of air depend upon the density of the air. Whether

slight differences of atmospheric pressure are capable of influencing the health is still an open question. No doubt certain very nervous individuals are affected by these differences.

The rarefied condition of the atmosphere at high altitudes exerts a decided influence upon the economy. It is best to consider this in conjunction with mountain climate.

Winds. The movements of the atmosphere which constitute winds produce variations in some of the factors of climate, chiefly in temperature, light, humidity, and pressure.

In a general way, the effect of winds is a renewal and purification of the atmosphere. Under rare conditions they may serve to transmit the germs of certain diseases. Their direct influence upon health has not been clearly defined.

Statistics show that on the European continent east winds coincide with an increase, west winds with a diminution of the mortality. A part of these results may be attributed to the force of the wind, to the state of humidity, and the purity or impurity of the air. Winds of moderate force exert a tonic and stimulant effect upon delicate persons, but strong winds, particularly if cold, will prove harmful by increasing the loss of heat and favoring sudden chilling of the surface.

An absolute calm is decidedly unfavorable, especially when associated with a high temperature, and when the air contains pathogenic micro-organisms.

Electricity. The last factor to be considered is the atmospheric electricity. The general effects of electricity are variable; they may be stimulating or sedative or even depressant. Beyond this nothing definite is known, the variations in the electric condition of the different stations according to the seasons not having been sufficiently investigated.

PARTICULAR CLIMATES.

We shall now take up the study of special climates, and in doing so it will be advantageous if we adopt the division of H. Weber, into maritime and land climates.

Maritime climates are those which are subject to the influence of the sea; they are insular or coast climates.

A few words will suffice, in view of the details already given in the preceding pages, for tracing their common characters.

Maritime climates are characterized by a relatively constant temperature, because the sea is warmed to a great depth by the sun's rays, and the radiation at night is lessened by the fogs.

The degree of humidity is always high. Other characteristics are: The regularity in direction and time of appearance of the local winds, the state of barometric pressure, the great intensity of the sunlight, the high proportion of ozone, the absence of dust, and the presence in the air of small particles of sodium chloride and of traces of iodine and bromine.

The physiological action of sea-air has been investigated by a number of authors, especially by Beneke. It has been found to influence strongly the general nutrition, even in a more marked degree than sea-baths. The surface of the body is cooled more quickly on the sea-coast than in the inland stations; the nutritive processes are active; the quantity of urine, the excretion of urea and of sulphuric acid are increased, while that of phosphoric and uric acids is diminished. The body-weight is also augmented. There is generally a fall in the number of respirations and pulsations; sleep improves, and the nervous system is slightly stimulated. The last effect may, however, be so marked that, in impressionable persons, it causes insomnia.

From the medical aspect maritime stations are divisible into summer and winter stations.

The former are frequented on account of the therapeutic effects of the sea-air and the sea-baths; the latter simply for their climate, being preferred by patients suffering from pulmonary diseases, particularly phthisis.

We shall postpone the consideration of the summer stations until we take up the study of chloride of sodium mineral springs.

The winter stations are classified, according to their degree of humidity, into humid, moderately humid, and dry. Among humid maritime stations are Madeira, the Canaries, the Azores, etc.

Madeira. Madeira, the best known and most agreeable, is situated 360 miles from the west coast of northern Africa, on the 33d parallel of north latitude and between the 16th and 17th degrees of west longitude. It is an island divided into two parts by a mountain range, the highest point of which is 6050 feet above sea-level. *Funchal*, the capital, is located on the southern coast.

The climate of Funchal is remarkably equable and mild at all seasons. Its chief characteristics are as follows: The mean annual temperature is 66° to 68° F., or about the same as that of Algiers.

The meau winter temperature is 63° F.; the lowest uight temperature is only 48° F. During the hottest summers the temperature does uot exceed 86° F.; and there is nearly at all times a refreshing sea-breeze, except ouly duriug the reign of the sirocco. The humidity of the atmosphere is considerable; the air is pure, free from dust, aud rich in ozone.

Funchal is built upon the declivity of a low mountain, which protects it from the north wiuds.

Patients usually go to Madeira at the end of September, and remain until April or May.

The priucipal effect of the climate is sedative, rarely depressing. It is best suited for chrouic catarrh of the larynx and bronchi, spasmodic cough, emphysema with moderate expectoration, and for irritable forms of phthisis.

One of the iuconveniences to which the climate gives rise is diarrhœa, which is quite common at Funchal. During the hot periods patients resort to Comacha, in the mountains, at an altitude of 2300 feet.

Teneriffe. Teneriffe is the most important of the Canary Islands. The climate of Santa Cruz, the principal station, is practically the same as that of Madeira, but patients do not find the uecessary comforts there.

The maritime stations which are moderately humid are divided iuto the warm and cool resorts.

Warm Stations. The most important warm stations are Mogador and Tangier (Morocco), Algiers, Cadiz, Gibraltar, Ajaccio, Palermo, the places on the Levantine Riviera, Venice, the stations of the Balkan Peuinsula, Lisbon, Vigo, la Corogne, Santander, St. Sebastiau, Portugalete, Biarritz, Arcachon, aud New Zealand.

The mean temperature of Algiers is, according to Martin and Folley, 68° F. During the season, from November to the end of April, it is 58° to 62°. The diurnal variations do not exceed 5 or 10 degrees.

Rains are abundant; storms occur occasionally. The nights are cool, and the days almost without dawn or twilight. The northwest winds are the most frequeut, and are sometimes severe. Iu winter the west winds predomiuate.

The dreaded sirocco comes from the southeast; it blows more often in summer than in winter.

Patients should not reside in the city of Algiers proper, but in the villas of the faubourg Mustapha Supérieur.

Chronic bronchitis, emphysema, pulmonary phthisis, chronic diarrhœa, and dysentery are benefited by the Algerian climate.

AJACCIO, on the island of Corsica, is very favorably situated. It has a mean annual temperature of 82°, and a mean winter temperature of 54°. The humidity is high, the climate being intermediate between that of Algiers and that of the Provence coast. Its action is both tonic and sedative.

The regions adjacent to the city should be avoided on account of the endemic prevalence of malarial fevers.

PALERMO, Sicily, possesses a delightful climate. The mean annual temperature is 62°; that of winter, 52°. The rain, which is quite abundant, gives to the atmosphere a soft, soothing quality. The sky is clear and luminous, and the summer less hot and scorching than at other warm stations. It is certainly one of the most agreeable spots where patients can dwell tranquilly in the midst of charming natural surroundings.

VENICE is a mediocre station, but deserves mention on account of the pleasures which it offers. Its mean annual temperature is 56°; that of winter, 38°. The monthly differences of temperature are not great, and the climate is quite uniform. Patients usually arrive in autumn and remain until spring, departing before the sirocco sets in from the southwest. The violence of the winds protects Venice from malaria.

TASMANIA AND NEW ZEALAND. Tasmania and New Zealand have been much extolled in recent years as climatic resorts. They are not of sufficient interest to warrant a detailed description. Regarding Tasmania, which abounds in picturesque and delightful spots, the northern and eastern portions of the island are preferable. The climate is, however, variable and windy.

New Zealand has a humid and wind-swept coast, and should be avoided by sufferers from pulmonary diseases.

In France, Biarritz and Arcachon are the most important stations pertaining to the class which we are at this moment considering. Both owe their climatic qualities, in part at least, to the Gulf stream. This great, warm current bifurcates at the level of the 46th parallel of north latitude, one branch ascending toward Ireland, the other inclining southward and skirting the coast of Portugal and Spain. Near the centre of the Bay of Biscay the latter gives off a secondary branch, which enters the bay, and, after washing its shores, passes northward as far as Cape Lizard, where it joins the principal northern branch.

Biarritz possesses a gentle and equable maritime climate, and is well suited for sea-bathing in the late autumn. As a climatic station it is in great favor with Englishmen and Russians. Its only inconvenience is the prevalence of winds.

Arcachon is both a summer and a winter resort. Its mean annual temperature is 60°, which is about 20° F. above that of Pau. Its winter temperature is 48° to 50°. Protected by pine forests and by high downs, it has a dry soil and a climate that is uniform, humid, and mild. The constancy of the temperature, the permeability of the soil, and the abundance of trees correct the excess of humidity. The air is very rich in ozone.

Cool Stations. A cool, moderately humid climate is found on the coast of England and Ireland, where the Gulf stream washes the shores. The influence of the Gulf stream is to raise the temperature of the water.

The winter temperature of these regions is a little higher, by reason of their proximity to the Gulf stream; the summer temperature being somewhat lower than that of other places having the same latitude. Fogs moderate the solar heat during the day, but also lessen the loss by radiation at night. The annual rainfall is quite high, or, more correctly, the number of rainy days is large, the quantity of rain, however, being no greater than that which falls at points considered much dryer, as San Remo, for example. The mean annual temperature is 48° to 50°; in winter it does not, in protected spots, descend below 42° or 47°, and even in exposed places it does not fall below 40° or 42° F. The prevailing winds are from the south or southwest, yet the local conditions in the different places are very variable. Probably the best spots for a winter's sojourn are to be found on the southwestern shore, where the temperature of the ocean is several degrees higher than at the northeast coast. The warmer places are in Devonshire and Cornwall. The hygienic and dietetic conditions of the English resorts are excellent.

As the winter resorts are very numerous, we shall only mention the most noted:

Penzance, on the Cornwall coast, has a gentle climate, which, however, is quite cold in winter and not uniform. The Scilly Islands are similar in climate, but the winters are less cold.

Torquay, in Devonshire, is a delightful spot and well protected. Its influence upon the sick is distinctly sedative; sometimes too pronouncedly so for tuberculous patients.

Teigurmouth, Salcombe, Dawlish, Budleigh-Salterton, Exmouth, and Sydmouth need only be mentioned.

Bournemouth, in Dorsetshire, contains one of the most important sanitariums of England; but the air here is lacking in all the proper marine qualities. Pine forests abound as in Arcachon, and conveniences are ample.

Undercliff, Ventnor, and Bonchurch, on the Isle of Wight, are very popular resorts. The best English sanitarium for phthisical patients is at Ventnor. The soil here is porous, the air mild, and the temperature equable. On the north it is sheltered by the downs of the island, but on the east it has no protection against the winds. At the national hospital for tuberculous patients the results have been quite favorable.

St. Leonard and Hastings are cold and exposed to the east wind, and are not suitable for phthisical persons.

Grange, in Lancashire, has a milder climate.

Rothesay, on the Isle of Bute, Scotland, has a gentle and equable, but very moist climate. The frequency of clouds and the absence of sunlight give to it a depressing influence.

The chief Irish resorts are Glengariff, Queenstown, and Rostrevor. The first has a very pleasant climate, and its environs are beautiful. Queenstown is quite similar, but less quiet.

The chief characteristic of these various resorts is a constant rather than a warm climate, a quality which adapts them particularly well to the needs of tuberculous patients.

The best effects are, however, not obtained in cases of confirmed phthisis, but in the cases termed scrofulous and in those in whom a predisposition to phthisis exists.

Dry Maritime Climates. Warm maritime stations are very numerous; the most important are those of the Mediterranean and of the Riviera di Ponente: Hyères, Costebello, Cannes, Antibes, Nice, Villafranca, Beaulieu, Boccabruna, Bordighera, Mentone, San Remo, Alassio; the stations on the Bay of Naples: Castellamara, Sorento, Salerno, Amalfi, the Island of Capri, the Island of Ischia, Catania, Syracuse, Malta, the Balearean Islands; and on the Spanish coast: Valencia, Alicante, Malaga; and in Egypt: Alexandria and Port Said.

Riviera. The stations of the Riviera are very similar in their climate; they are scattered along a narrow strip of coast which is open toward the sea, but bordered inland by a protective range of mountains. The soil is calcareous.

The mean winter temperature is from 48° to 54°; the atmosphere is tolerably dry, the humidity being 65 to 70 per cent.; the sky is bright, sunshine abundant, cloudy days are few; and although there are forty to fifty rainy days during the "season" of six months, the patients are able to be out of doors for several hours every day. The land and sea breezes alternate with great regularity.

December and January are very calm; the dry and cold mistral does not begin to blow until April.

There are some inconveniences in the Riviera, mention of which should not be omitted. The atmosphere is at times very dusty, mosquitoes are annoyingly abundant, and the difference between the temperature in the sun and in the shade is often so great that special precautions must be taken to avoid chilling.

The climate in the Riviera is distinctly tonic and stimulant, and has a salutary influence upon a great variety of diseases, among which may be named general debility, scrofula and anemia, diabetes, gout, rheumatism, chronic catarrhal affections of the larynx, the bronchi, the stomach and intestines, and non-irritable forms of phthisis. Persons suffering from nervous excitability or circulatory instability, or from florid forms of pulmonary phthisis should refrain from going to the Riviera.

A few words may be said as to the most important stations in the Riviera. Hyères is situated four miles from the sea, and has a mean annual temperature of 60°; that of winter is 48°.

The middle of the day is warm and best adapted for promenading; very cold days are rare; but winds are frequent, and among them is the mistral, which has a baneful influence upon the patients. The climate is less stimulant than that of Cannes or Nice.

The mean annual temperature at Cannes is 61°, that of winter 50°. The mistral is not so frequent as at Hyères; the prevailing wind is from the south. Temperature-changes are abrupt, the nights are cool, the atmosphere dry. Cannes possesses an admirable beach for bathing, and the accommodations are excellent. It is the best and most aristocratic of the Riviera resorts, but very expensive.

Antibes has a very mild climate and is pleasantly situated.

Nice is the oldest and most popular winter resort. It owes its importance to its magnificent situation on the Bay of Anges, but possesses the disadvantages of a city. Almost completely protected against the north and east winds, it is freely exposed to the others, notably the land and sea breezes. During the winter a strong wind,

unfavorable for phthisical patients, blows, it has been calculated, for thirty-three days. The mistral is not common.

The number of rainy days is smaller than at other points, although rain falls sometimes in great abundance. Fogs are unknown at Nice; snow is very rare. During fifty to sixty days of the season patients are kept indoors by rain or violent winds. The mean annual temperature is 62°; the mean winter temperature 47°. For the six months of the season the mean temperatures are as follows: November, 53°; December, 48°; January, 47°; February, 49°; March, 52°; April, 58°.

Cannes and Nice fulfil practically the same indications. The season extends from November to April.

Monaco and Monte Carlo are well situated, and would be more frequented if gambling were not favored there.

Mentone is the warmest resort on the littoral, having a mean annual temperature of 63°, and a winter temperature of 49°.

The sky is clear and bright, except mornings and evenings, when the air is often cold and damp. It is a quiet, rather sombre resort, well suited for excitable phthisical patients and those subject to hemoptysis. The conveniences are very good.

San Remo is charmingly situated and enjoys a delightful, salubrious climate. It is well protected, and is rarely visited by the disagreeable east wind (vento greco).

The resorts of the Bay of Naples are very warm and stimulating. They should be selected only for apathetic and lymphatic individuals.

Catane, near Mt. Etna, is a good winter resort. Malaga is stimulating; Valence is hot and humid, and deficient in proper accommodations.

Sea-voyages. The study of maritime climates is best discussed by a consideration of the value of sea-voyages, which are coming into favor as therapeutic measures, particularly since their careful investigation by Peter.

They are of most importance in their relation to the treatment of phthisis. It is well known that this disease is less common in the navy than in the army, a result clearly attributable to the more active life of the sailor and to the purer atmosphere.

The atmosphere, it should be remembered, is not pure at a less distance than 2000 yards from the shore. Sanitariums which are built near the sea are for this reason not so capable of producing good effects as a sea-voyage.

A long sea-voyage is generally prescribed, the favorite one for Europeans being a trip from England or France to Australia.

A sailing-vessel is preferable to a steamship, for a number of reasons. The passage is slower, the temperature-changes are more gradual, the cabins more commodious, there is less dust, and one is not annoyed by the constant working of machinery. The progress of the vessel is slow and gentle, and engenders a restful feeling. If the vessel doubles the Cape, so much the better. Its only disadvantage is the dead calm which the ship meets at the equator, inasmuch as this causes the atmosphere to become humid, heavy, and oppressive. The duration of the voyage is from 70 to 90 days. It is customary to sail in November or the beginning of December.

Such a voyage entails a complete revolution in habits; it is a new existence, deprived, it is true, of pleasures, but also free from care. Sleep and appetite are improved, and everything is conducive to a perfect repair of a constitution shattered by excesses or chronic disease. In warm latitudes the patient can remain in the open air for at least fifteen hours in the day—a most important feature. A truly pure atmosphere can only be found in the middle of a desert, on the summit of mountains, and on the open sea. The last has the additional advantage that it offers a climate of remarkable uniformity. The humidity may be a little unpleasant, but tends to diminish cough and to calm the nervous system of excitable patients, and also favors sleep. In short, the general action of sea-voyages may be said to be tonic and sedative.

They are indicated in essential diseases of the nervous system, in the convalescence from pneumonia and pleurisy, in scrofula, in the dry forms of asthma, in laryngitis, and in the slower types of pulmonary phthisis. The contraindications are advanced age, marked debility, rebellious forms of dyspepsia, disease accompanied by delirium, and, finally, an excessive tendency to sea-sickness.

Phthisical patients who are frequently obliged to make several voyages must, during the intervals, necessarily take great precautions. Lindsley justly remarks that it is absurd to expect a cure within a short time; he points out, however, that restoration is not rare, a fact which the interesting statistics of Williams go far to establish.

Other voyages, besides the one mentioned, have been recommended. If the one to the Cape is not taken, that to India is of use, but necessitates a prolonged sojourn in tropical seas.

Patients going to Australia often disembark at points not suited to their disease, or reside in large cities, where they are tempted to commit excesses.

Australia was at first vaunted as one of the best resorts for consumptive patients, but in recent years it has been vehemently abused. The truth, however, is that the climate is favorable to cases of tuberculosis if the place of residence is properly chosen. The month of March is the most delightful season on the Australian Continent.

Land Climate. The land climate may be divided, as already stated, into the mountain climate and that of the plain. The former has acquired great renown in recent years with respect to the treatment of pulmonary phthisis. Jaccoud is one of its most ardent advocates in France.

MOUNTAIN CLIMATE. The characters of the climate of mountainous regions vary, necessarily, with the altitude and latitude, with the isothermal lines, and other elements; but there are certain features which are common to all, and upon which, to a large extent, the beneficial effects of the climate depend.

The temperature varies with the altitude, an elevation of 700 yards corresponding, in winter, to a fall of one degree.

The humidity presents no fixed character; generally it is quite low and passes through regular changes, diminishing toward noon and augmenting toward evening.

The quantity of rain usually increases with the altitude, but bears no relation to the humidity in the mountains; in winter it is generally replaced by snow.

Fogs forming in the valleys rise to the middle strata of the atmosphere, but are seldom seen at great heights. The atmosphere of high altitudes is remarkably transparent.

A very important feature of mountain climate is the great intensity of the direct solar heat. Thus Frankland records that he found the temperature at Davos-Dörfli, at 2.50 P.M., December 21, 1873, to be 45°. At Greenwich, at 3 o'clock of the same day, a temperature of 21.9° was observed. Notwithstanding this great solar heat the air remains cool.

The light in the mountains is very intense and ozone is abundant. Unfortunately, very little is known in regard to the electric conditions of the atmosphere. Winds vary with different regions, but, as a rule, are frequent and strong. They are more violent in summer than in winter.

The soil is generally rocky, and, therefore, dry.

The chief characters of the mountain climate may be summed up as follows: The low barometric pressure, the intensity of the direct heat without a corresponding warmth of the atmosphere, and the consequent low temperature reigning in the shade and at night; the dryness of the atmosphere in spite of the abundance of rain or snow; the strength of the winds, the great purity and the richness in ozone of the atmosphere, the splendor of the light, and the dryness of the soil.

It is very evident that a climate possessing such qualities must necessarily have a marked influence upon the system. The cutaneous circulation is stimulated both by the coolness of the atmosphere and by the heat of the sun. The dryness and the frequent renewals of the atmosphere favor cutaneous evaporation.

During the first few days succeeding the arrival in the mountains the action of the heart is slightly accelerated; but this disappears and gives place to an increase in the cardiac energy. Respiration is similarly modified, although observations on this point are contradictory.

It is important to distinguish the early effects, those following the ascent from those resulting from a prolonged stay at a high altitude.

There is, in the beginning of a residence at an altitude, a notable increase in the functions of respiration, digestion, and nutrition, and it is very natural that Marcet, Mermod, and others should have found an augmentation in the excretion of carbon dioxide. But what are the effects of a permanent sojourn? The general belief, based upon the known facts of a rarefied atmosphere and a smaller proportion of oxygen, has been that there is a depression of functional activity; a view that was strengthened by the studies of Lombard, of Jourdanet, and of Bert. These writers held that at high altitudes there was a tendency to the production of a relative asphyxia, a condition for which Jourdanet proposed the term anoxhemia. These views, however, are certainly theoretical.

In reality the air always contains more oxygen than is necessary, and the equilibrium of the external and internal gaseous tension is rapidly established at any altitude.

It should also not be forgotten that it is the processes of nutrition which regulate the consumption of oxygen, and that altitude can affect the latter only indirectly. The question can only be settled by a comparison of the data of observation.

We may refer here to the interesting studies of Veraguth upon the physiological action of the climate of Upper Engadine. He has found that the respirations are increased by two movements a minute during the first week, but subsequently become again normal. The relative volume of the expired air is at first augmented; later it diminishes, but yet remains slightly higher than on the plains. The absolute volume, after a temporary increase during the first week, falls below that noted on the plains.

The author applies the term relative air to the volume of air respired and measured by the spirometer (that of Bellangé).

Veraguth also noted a constant increase in the quantity of carbonic dioxide and watery vapor exhaled from the lungs. During the first days of the sojourn he also observed a slight increase in diuresis, which later gave way to a persistent diminution of the urine. The urea was at first decreased, then slightly increased, and subsequently again diminished. No changes were found in the excretion of uric acid. The bodily temperature was not modified. The diminution in weight which was observed in the patients disappeared on their return to the plains.

One of the results of life in the mountains appears to be an increase in the dimensions of the chest, amounting to one or one and a half centimetres in the circumference of the thorax. Weber found it in young persons after a sojourn in the mountains of from three to twelve months. It might seem justifiable in explanation of this fact to invoke the effects of simple growth, but it is unquestionable that mountain-climatizing is capable, particularly in youthful persons, of increasing the diameters of the chest; and proof of this is found in spirometric measurements.

As a general rule, the appetite is augmented, at least in the beginning, up to the altitude of 5000 feet, although there are patients in whom it is decreased temporarily at a height of 2400 to 4000 feet. When anorexia persists, it is an indication for a return to the plains.

On the whole, we may ascribe to mountain climate a favorable influence upon nutrition and muscular energy, and upon neurasthenic states, provided the sleep is sound.

Winter Resorts. For practical purposes mountain resorts may be divided into winter and summer stations, although a few are suited for the transitional periods.

Among winter stations we again distinguish between those situated at a moderate height and those of great altitudes.

As regards the relative value of maritime and mountain resorts, concerning which there is considerable discussion, it may be said that both act by offering the individual those surroundings which are most favorable for the repair of the lesions caused by disease. Although mountain climates are indicated by certain states and contraindicated by others, for the warfare against tuberculosis they are of great value and importance.

The principal elevated stations are in the Engadine, among which Davos is the most renowned. It is situated in a wide valley, lying from northeast to northwest, and occupies the lower part of the slope of the mountain-range. Its altitude is 5100 feet, the mean barometric pressure 630 millimetres. The mean annual temperature is about 37°, but in summer the thermometer rises to 76°, in winter it falls to 14° F. below zero. The differences between the diurnal and nocturnal temperatures are equally great; often also those between two successive days.

The temperature during the months of the season is nearly always several degrees below zero, with a mean for January of 20° below But these figures do not indicate the real temperature to which the patients are exposed, for the direct heat of the sun is very great.

The air is quite humid, more so in the winter than in summer. According to Steffen, there are only 4.8 grammes of watery vapor in every cubic metre of air, so that the inspired air raised in the lung to a temperature of 100° can take up an additional quantity of 38.7 grammes of water, since air at 100° holds, when saturated, 43.5 grammes of vapor.

There are at Davos many snowy days, and the snow covers the ground constantly from the middle of November until the middle of March. The winds are less violent in winter than in summer. The atmosphere is clear and transparent, and its comparative calmness diminishes the effects of the cold.

[Patients should leave Davos early in April, before the snow melts, and return late in May or June.—Ed.]

The winter season, which is the best, begins in November; the summer season in June. The patients are subjected to a dietetic regimen and to hygienic practices, such as ablutions, or even to hydrotherapy.

At Davos-Dörfli the conditions are practically the same as at Davos, except that there the sun shines about an hour longer.

Davos-Frauenkirch and Wiesen are situated somewhat lower.

The latter is not far from Davos, and is located on a picturesque declivity overhanging the gorge of the Landwasser, eighty feet lower than Davos. [In cases where the patient ought not to go directly to as great an altitude as Davos, he may stop at Seewis (3000 feet), or at Ragatz (1700 feet).—Ed.]

The climate of Wiesen is milder, the winter a little shorter, but the spot is less well-protected, and, though simpler, has almost too much solitude.

In the Upper Engadine, the highest valley in Europe inhabited throughout the year, we find Saint Moritz, 6090 feet; Maloja, 6000 feet; Pontresina, 5915 feet; Maria Sils, 5700 feet; and Samaden, 5670 feet.

The winter sanitoria are Saint Moritz and Maloja. [This is a mistake, Maloja is now only open in summer.—Ed.] The valley of the Upper Engadine is not so favorably situated as that of Davos. It is colder, and is better adapted as a summer resort.

The four Alpine stations which have been mentioned, Davos, Wiesen, Saint Moritz, and Maloja, have practically the same tonic qualities, but differ sufficiently in their stimulating properties to make a choice for different types of disease proper.

Wiesen is least, Saint Moritz and la Maloja more stimulant, and Davos is intermediate.

A new sanitarium has lately been constructed at Leysin (4757 feet) in the Canton of Vaud.

[All alpine winter resorts subject the patient to great cold, but this is very well borne in most cases, many patients sleeping and walking in freezing temperatures.—Ed.]

Santa-Fe-de-Bogota, in Colombia, is the best known of the resorts of the Andes Mountains. Although on a latitude of 4° 30′ north, its elevation, 4800 feet, tempers the heat of the tropical climate.

The mean annual temperature is 58°; the seasonal changes are extremely slight; a perpetual spring reigns, which makes Bogota a most delightful resort, with a vegetation of the rarest beauty. The therapeutic results obtained there have been excellent.

Quito, Arequipa, Jauja, and Huancajo are equally good resorts.

The Asiatic and African stations are interesting from a scientific standpoint, but have as yet not acquired any practical importance. [Very favorable results in cases of phthisis have followed residence in Kimberly, Cape Colony, the Orange Free State, and the Transvaal, where altitudes of about 4500 feet are readily found. The

capital of the Free State Bloemfoulein is warm, with some cold winter nights, according to Williams. The average minimum temperature is 55° F., and the maximum 82° F. The rainy days are seventy. This country is accessible by comfortable steamers and by railroads.—Ed.] The Himalayas present from their base to their inaccessible summits every variety of climate. [As a rule, the Himalayan climate is stimulating but hot, and it possesses too great a rainfall to be useful in the treatment of phthisis.—Ed.] Darjeeling (8000 feet), in Western Bengal, has some reputation. Connor (5000 feet), not far from Madras, is also quite popular.

At moderately elevated stations patients can have the opportunity of preparing themselves for higher altitudes; sometimes, also, these resorts are frequented during the intermediate seasons.

The French stations of this class are also known for their thermal springs, and provide a double means of treatment. Among the more important, Le Vernet, Amelie-les-Bains, and Gréoulx may be cited.

Vernet, in the Eastern Pyrenees, has an altitude of 1500 feet, and a mean temperature for the last three months of the year of 53°. The climate is calmative, but inconstant.

Amelie-les-Bains, also in the Eastern Pyrenees, is the southernmost French resort. The climate has a sedative influence, and is suitable for autumn and winter. The mean temperature is 49°; the altitude 700 feet.

Gréoulx (Basses-Alps) is a station frequented in autumn; it has an altitude of 850 feet and a mild and equable climate.

Grasse, another French resort (Alps-Maritime), has an altitude of 850 feet. It is a winter resort.

There are a number of resorts in Switzerland, chiefly on the borders of Lake Geneva.

Vevey is very agreeable during autumn; patients can take the "grape-cure" there. It has an altitude of 1000 feet and a mean annual temperature of about 50° F.

Montreux has a climate that is even milder. It is customary to take the grape-cure in autumn, and it is a pleasant place in which to pass the winter and spring.

The patients generally are domiciled in the little hamlets that dot the country between Vevey and Villeneuve, such as Clarens and Vernet, the altitudes of which vary from 925 feet to 1200 feet, and the mean annual temperature 50° F.

The climate of this region is both sedative and invigorating. Other Swiss resorts of this type are Aigle, Bex, Sion, and Lugano.

Meran, the elevation of which is 1000 feet, is situated on the banks of the Adige, on the southern slope of the Tyrolese Alps. Its mean annual temperature is 50°. It is a station for the grape-cure, and is frequented both in autumn and winter, particularly during the winter. It is important not to arrive before the drying of the swamps and marshes. Botzen and Gries, somewhat lower than Meran, serve to contain the overflow of visitors from the latter place.

The winter resorts are sought especially by consumptive patients; but it is evident, when we consider the number of qualifications possessed by them, that these stations may in summer be beneficial to other diseases than phthisis. This is notably true of Saint Moritz.

SUMMER RESORTS. Among summer resorts there are a number which are suitable for the entire year, others exclusively for the summer season. Several possess mineral springs, which are made to play a *rôle* in the treatment.

The most important of these for consumptives is Görbersdorf, in Silesia, where Brehmer more than twenty years ago founded the first mountain sanitarium. Its altitude is 1400 feet. The patients are subjected to a complex "cure," into which the use of air, hydrotherapy, and special treatment enter.

The season at Görbersdorf includes the spring, summer, and autumn. The treatment produces effects that differ from those obtained at higher levels; it fulfils special indications, and is particularly useful for those who cannot endure high altitudes.

It is said that Dr. Ungern, who was afflicted with phthisis, visited Görbersdorf, but, on obtaining no relief, went to Davos, where he recovered completely. The reputation of the latter resort dates from that time.

Falkenstein on the slope of the Taunus, near the stations of Soden and Kronberg, is a late rival of Görbersdorf. It has a sanitarium, established by Dr. Dettweiler, where the open-air treatment prevails. Its altitude is 1150 feet. The French sanitarium of Canigou has been modelled after the type of that of Falkenstein.

There are many other summer resorts, but they are not frequented by consumptives. We may name Mornex, Monnetier, St. Gervais, a short distance from Chamounix—Chamounix near the base of Mount Blanc—Weisenberg, Lenk, Heustrich, and others. Or, again, we

may mention St. Beatenberg, which overlooks the lake of Thün, Sonnenberg, Engelberg, and Axenstein.

The influence of all these resorts upon the organism is rather more sedative than tonic. They may be recommended to patients who wish to prepare themselves for the higher altitudes.

Other summer stations besides those in Switzerland exist in the French, the Bavarian, and Tyrolese Alps, and the Pyrenees, in the Apennines, and on the Carpathian Mountains. Among these, Panticosa (5000 feet), on the Spanish side of the Pyrenees, is much frequented by phthisical patients.

Indications for Mountain Climate. As a general rule, high altitudes are adapted only for the treatment of disease in quite young and vigorous persons, or, at least, in those possessing a certain degree of resistance. The pathological states that are amenable to it are numerous; the most frequent are anæmia, chlorosis, chronic pharyngeal and bronchial catarrh, paludal anæmia, abdominal plethora with tendency to hemorrhoids, hypochrondriasis, rebellious neuralgia, light forms of hysteria, nervous polyuria, nervous asthma without emphysema or cardiac lesion, imperfect development of the thorax, predisposition to or established phthisis, dyspepsia, and retarded development in children.

Heart-affections, arterial atheroma, chronic bronchitis with dilatation and emphysema, epilepsy, acute articular rheumatism, constitutional debility, and the extremes of age are contraindications.

The resorts with a moderate elevation are often beneficial when the higher altitudes prove harmful. Thus, in simple cardiac weakness or in aneurism of the aorta the patients do well at altitudes from 1000 to 1400 feet.

Undoubtedly the most important therapeutic use of mountain climate is in connection with the treatment of pulmonary phthisis. It seems to have had its birth in Peru, where, according to Smith, it has been a long-established custom to transport the consumptives to the peaks of the Andes Mountains. In Europe the treatment was inaugurated by Brehmer, at Görbersdorf, about thirty years ago. In the present epoch the higher altitudes are most in favor, and are resorted to especially in winter. This modification of the original plan was brought about by the writings of Küchenmeister and Thomas, who have also pointed out very clearly in what forms of phthisis the climatic treatment is applicable—namely, in the slow, torpid types, affecting moderately robust persons.

To particularize, we may name the following pathological states as those in which the treatment may prove of service: predisposition to phthisis, chronic apical pneumonia, tuberculous infiltration of one apex, chronic bronchitis without emphysema, pleuritic exudates, non-purulent in character; multiple but limited caseous foci, small cavities that are stationary, chronic hoarseness without much cough, profuse night-sweats, depending upon one of the preceding conditions or upon a feeble state of skin. Erethismic forms of phthisis, acute febrile states, pronounced hereditary tendency, interstitial and laryngeal tuberculosis, and that variety consecutive to diabetes are contraindications to the climatic treatment.

The results so far achieved are quite encouraging. Among a total of 75 patients, spending altogether 1875 months in the mountains, Weber found that 18 had permanently recovered, 28 were improved, in 14 the success was doubtful, in 15 the disease continued to progress.

[In his recent monograph on "Aërotherapy," Williams, of London, gives the results reached in 246 patients suffering from phthisis who were sent to high altitudes. A cure was effected in 101, or 40.89 per cent.; great improvement in 73, or 29.55 per cent.; some improvement in 32, or 12.95 per cent. Five remained stationary, and 36 became worse.—Ed.]

The general direction which the treatment is to assume cannot be precisely stated. It depends upon the constitution of the patient, his resistance, and capacity for reaction.

In many instances it is difficult to decide positively upon the value of the treatment, since it is applied to patients under the most favorable conditions under which equally good results are obtained by other methods.

Debilitated persons should spend the summer at a moderate altitude, preferably where there is a forest, and the winter in a temperate or warm climate.

Climate of the Plains. The climate of the plains in our studies here comprises only winter resorts. It is either dry or moist, hot or cold.

Dry and Hot Climate. The African desert represents the type of a dry and hot climate. The heat of the air is intense, the atmosphere is dry, but at night the temperature falls to a low point. The sky is serene, rain is a rarity, and dew is abundant.

Weber reports a number of instances in which phthisical patients

did very well while living almost in the open desert and nourishing themselves exclusively on the products of the chase. When the disease is advanced it is wise to avoid such severe exercise, and it is customary in practice to recommend Cairo, Upper Egypt, or a voyage on the Nile.

Cairo may be taken as the type of hot and dry stations. Its mean annual temperature is 71°; in the six months from October to March it is 64°. The nights are cool.

Notwithstanding the dryness of the climate the atmosphere contains a large amount of watery vapor (absolute humidity), which is exactly the reverse of what obtains in the mountain climate.

The season extends from the middle of November to the middle of March. In April the patients begin to be annoyed by the desert wind, which is difficult to support and dangerous to health.

The climate of Cairo is both tonic and stimulant, particularly to the newcomer, in whom it frequently produces a state of nervous excitement. These effects, which are generally ascribed to the perpendicularity of the solar rays and to the excessive dryness of the atmosphere, pass off after a certain time. In such a climate the clothing, the food, the habits of life, as a whole, should be objects of special study and attention.

Cairo is of value only in the early stages of phthisis, but to what extent it is beneficial has not been definitely determined.

Good results have been obtained in chronic bronchial catarrh with emphysema, in chronic rheumatism, in gout and diabetes, in chronic nephritis, in heart-disease complicated with chronic catarrhal affections, in certain forms of dyspepsia, in rebellious neuralgias, and in the exhaustion from overwork.

The dry and cold climates are so rarely employed in the treatment of disease that their considerations may be omitted.

Warm and Moist Stations. Pau, Dax, Pisa, and Rome are the principal resorts having a moist, warm climate.

Pau (Basses-Pyrenees) is one of the most popular of these resorts. Its mean annual temperature is 56°; from November to April, 44° to 46°.

The air is, as a rule, tranquil, but at times very strong winds prevail; rain is abundant, and falls for at least eighty to one hundred days between November and April. The sky is generally cloudy; dust is rare.

The climate is sedative without being depressant, and is chiefly of

value in conditions of excitement, in cases where a predisposition to nervous affections exists, and in irritable states of the mucous membrane of the air-passages associated with dry cough.

The gouty and rheumatic also do well at Pau, but those disposed to cerebral or pulmonary congestions, or to hemorrhoidal fluxes, should avoid it.

Dax (Landes) is frequented on account of its hot springs (85° to 142° F.). The atmosphere is moist and moderately warm.

Pisa, in Tuscany, has been renowned from ancient times. Its mean annual temperature is 60°, or nearly that of Rome; from November until March the mean temperature is 47°. The diurnal variations are moderate; the precipitation is abundant, especially in autumn. The season extends from November to spring.

Rome is a mediocre station, offering more attractions to the tourist and the artist than to the sick. The three months of spring, besides October and November, are the best months in which to dwell at Rome. Phthisical patients and those with neuropathic traits make up the largest portion of the *clientèle* of Rome.

AMERICAN CLIMATIC TREATMENT.

The fundamental facts governing the effects of climate upon human beings having been considered in the opening remarks upon European resorts, it only remains for us to discuss the individual regions in America which are or may be employed for the treatment of disease.

These regions may be divided into the high altitudes, the medium altitudes, and the low altitudes, the type of the first being found in Colorado, of the second class in North Carolina and in New York, and of the third in Georgia and southern California.

The Colorado climate without doubt offers the best results for the majority of cases of phthisis, but it is always to be remembered that in the employment of climate for the cure of disease selection for the needs of the individual case is as important as is the selection of a drug in each case where medicinal measures are used. No more vital mistake can be made by the physician than to suppose that every case of consumption will be benefited by a visit to Colorado, and an error of almost equal gravity is the belief that a visit to this or any other region is all that is necessary for a cure, temporary or permanent. Recoveries often occur, it is true, but it is also a fact

that fatal relapses are prone to take place if the patient undertakes to return to his former residence. There are, of course, exceptions to this statement; but nevertheless he who goes to a climatic resort for relief of some constitutional disease should go rather with the idea of a permanent residence than a temporary visit.

The advantages of Colorado as a health resort for consumptives in particular rest upon identical conditions with those found in Europe in places of similar altitude; and care should be taken that only those places in Colorado which are to some extent protected from high winds and which have a low percentage of humidity are chosen, although the relative humidity of the whole State is about 46 to 58 per cent. in comparison with the Atlantic and Pacific Coasts, where it is as high as 75 to 78 per cent. Rain falls in Colorado on about eighty-five days in the year, but often for only a small fraction of these days, and the average amount varies from 8 to 22 inches; the fall at Colorado Springs, which may be taken as the central health-point of this State, being about 15 inches. To those unacquainted with the average rainfall of other parts of the world, this may not seem a small amount, but when we consider that the average in New York City is 45 inches and in Philadelphia 41 inches, and is estimated at 36 inches for the world in general, the Colorado area is very low. The rainiest place on earth is supposed to be Assam, Asia, 610 to 905 inches yearly. During the months from October to April rain very rarely falls, and in the summer months generally falls during thunder-storms, and the number of cloudy days is therefore very few, which is, of course, a very desirable feature of the climate, since it enables the patient to be almost constantly exposed to fresh air and sunshine. Indeed, it is worthy of note that Colorado offers a greater number of hours of sunshine than can be found at any European resort, and the power of the sun is so great that invalids sit on piazzas in winter with comfort. Thus, Solly states that the temperature in the shade may be 30° and in the sun 92° in the morning, or 40° in the shade and 100° in the sun in the afternoon.

From what has already been said in earlier pages of this volume, atmospheric temperature is a comparatively unimportant factor in the treatment of phthisis. In most places in Colorado the changes between night and morning in temperature are very marked, as is always the case where a mountainous region is far removed from those influences which modify tendencies to sudden changes, as, for example, the presence of large bodies of water. The mean temper-

ature of Denver or Colorado Springs in no way represents, therefore, the extremes to which the individual may be exposed. Thus, in Denver, the mean temperature for the year is 50°, while the extremes have reached 25° below zero on the one hand and 101° on the other.

The mean temperature by months varies from 27° in January to 72° in July, 80° in August, and 40.5° in December; winter scarcely begins until January and lasts till toward the end of March; but high winds prevail the greater part of the year, so that only about 30 or 40 days are still.

The altitudes of the various points in Colorado which may be or are commonly resorted to are of course very different. Denver, because of its smoke from the furnaces, is hardly the place to direct the invalid for a prolonged stay; although the patient had better in every case go to Denver or Colorado Springs when he first reaches Colorado, in order to consult some one of the eminent physicians of these places as to the best particular spot where he should locate, and in order that he may from time to time get further advice as to medicinal treatment and prognosis. It is to be remembered that these towns are not in a mountain region, but in a great prairie land. The altitude of Denver is 5000 feet, while that of Colorado Springs is 6022, the latter point being 69 miles nearer Pike's Peak and 75 miles south of Denver.

It is not necessary in this place to discuss other and less well-known but equally valuable resorts in Colorado, such as Manitou Springs (6500 feet), Idaho Springs (7800 feet), or Boulder (5409 feet), or any of the resorts in the Platte or Bear Creek canons, at from 6000 to 8000 feet, since the local physicians are the best judges of the individual spots to be chosen. It is necessary, however, to warn physicians not to send patients to Colorado who are too far advanced to hope for relief, or who have no means to support themselves without work, since the ingress of many hundred persons so placed as to be reliant on their own efforts has cheapened all forms of hand labor and mental work very greatly.

In addition to the great disease for the relief of which the climate of Colorado does so much, there is very positive proof of its value in other states, both pulmonary and cardiac. Denison and Solly have shown that a large percentage of persons suffering from asthma are benefited, provided the asthma is not associated with emphysema. The latter condition, if present, always makes the patient worse, and so increases the distress as to make it dangerous to send the emphy-

sematous to this region. Similarly, cases of asthma who have dilated or incompetent hearts should not be sent to Colorado, as a rule. The presence of bronchitis, acute or chronic, with or without bronchiectasis, is also a contraindication to Colorado climate. In convalescence from pneumonia or pleurisy the question as to the value of Colorado climate must rest on the vigor of the patient. If he be relaxed and feeble, a more moderate climate should be chosen; but if, on the other hand, he is fairly vigorous, the increased pulmonary exercise is often of extraordinary value. The influence of a climate such as is found in Colorado upon the circulatory apparatus is very great. At first it causes an increased rapidity of the heart-beats, which may continue in those who have cardiac disease, and with whom the climate does not agree. In the healthy, on the other hand, the normal pulse-rate is very soon restored. In all cases which remain for any length of time in the climate of Colorado, and with whom it agrees, there is often for a short space of time an apparent increase in the cardiac power. For this reason excellent results often ensue in young persons who have slight cardiac dilatation, but rarely are reached by older or feeble persons with similar conditions. Care should always be exercised in these cases that the patient does not go to too great an altitude at first, and that exercise should be very gentle in form for some time, lest the dilatation be increased before benefit can be produced. As a rule, however, lower altitudes than those of Colorado should be chosen for all such patients suffering from either cardiac or vascular lesions.

In cases of neurasthenia, needing bracing air and out-door life, the climate of Colorado is very useful, provided that there is not associated with the neurasthenia disorder of the circulation of a marked type. Should there be great nervous excitability the patient should not be sent to Colorado.

Similarly, it may be considered as a rule that in cases of renal disease a lower or more moist and equable climate is to be sought than one such as is typified by Colorado, since the sudden changes of temperature found in nearly all high-mountain resorts is of great disadvantage through its effects on the skin and kidneys. Again, persons suffering from catarrh of the stomach and bowels should avoid Colorado as a rule, and if hepatic trouble is present seek a lower, and, if possible, equally dry climate, though, in a certain proportion of cases, residence in these higher altitudes produces good effects if the greatest caution is exercised to avoid sudden chilling of the sur-

face by the use of woollen clothing and by remaining housed at early morning and evening. It is a curious fact, too, that if a tendency to attacks of diarrhœa originate at a low level, a visit to an altitude will often be productive of good result, and it is equally curious that the reverse holds true. In any event, for cases of diarrhœa or catarrh, that locality which has a dry soil and atmosphere is most essential.

Passing from a consideration of the effects of high climatic treatment in America, we come to those places having a moderate elevation, represented best by the Adirondacks, in the State of New York, and by Asheville, in North Carolina. The general altitude of the former is 1500 to 3000 feet, and of the latter 2200 feet. In the Adirondacks there is a relatively high humidity, but a great purity in the air, which is also very still as compared to the aërial conditions in Colorado. Further than this, the irregular configuration of the land, its heavy growth of timber, and its great number of lakes render sudden changes in temperature and high winds comparatively infrequent. The extremes between summer and winter temperatures are, however, very great, as are also those between morning and evening; but even in winter the heat of the sun is sufficient to make exposure to the open air comfortable.

At Asheville and its neighboring country, a region which we shall take as the type of an area having a medium elevation among American health resorts, the humidity is about 64 per cent. higher than in Colorado, and less than on the coast, which is an advantage to some cases of phthisis or irritative bronchitis, in which the dry air of Colorado often acts as an irritant.

A further advantage of Asheville is to be found in the influence which it exerts upon the circulation, which is important in many cases of phthisis, since slight cardiac dilatation and marked cardiac feebleness is a very frequent complication of this disease, preventing residence in high altitudes, or, when residence is possible, forbidding the exercise so essential to all cases of this character. In those cases having much shortness of breath and cardiac palpitation, an altitude which is equivalent to that of the Adirondacks or Asheville is always to be preferred, and the higher resorts only visited, if at all, after marked improvement has taken place in the cardiac, if not in the pulmonary condition. A further advantage in these moderate altitudes is that the change on returning home is not so marked as on a return from Colorado. On the other hand, it has been the writer's ex-

perience that persons contracting phthisis at places in the West having an altitude equal to Asheville, as, for example, many places in the Dakotas, do better in Colorado, since the change in altitude in such a case is equivalent to the change made by the patient going from Philadelphia to Asheville. The facts as to the advantage of clear days in Asheville, taken from the United States Weather Reports, show that since 1888 there have been 25 clear days out of every 30. The temperature of Asheville varies from 16°, as the coldest recorded in winter, to 59.30° as the warmest in that season of the year, and in summer from 30° to 88°, but the mean minimum for winter is 44.95° and the maximum 56.54°, while in summer it is 55° and 56° and 76.76°. It will be seen, therefore, that this region has the advantage of comparatively slight changes in the seasons and in diurnal temperatures, and that it occupies the position of being a moderate climate capable of doing great good, as experience has proved in many cases, and as theory would indicate, and with distinct indications for its use based upon the rules already laid down for the choice of climate and for individual cases in particular.

There still remain to be mentioned as types of low-level resorts, Thomasville, Georgia (330 feet), Lakewood, New Jersey, and San Diego, Los Angeles, and Pasadena, California, and parts adjacent.

Thomasville and Lakewood gain their advantages through their dry, sandy soil and clear air, and are very useful in cases suffering from irritation of the respiratory mucous membrane.

The climate of San Diego is dry and warm, equable and soothing. Its warmth depends upon its southern latitude and its equability upon its protection by mountain ranges and the nearness of the Pacific Ocean, which, through its black Japan current, tends to prevent excesses of cold in winter and heat in summer. Thus in winter the mean temperature varies from 60° to 70°; the minimum temperature for December, January, and February being 54°, and for June, July, and August, 68°. The rainy days in the year are about 20 to 30, and the relative humidity about the same as Asheville, namely, from 60° to 75°. The character of the climate, while not stimulating, is nevertheless most useful for the feeble, and allows of residence without the necessity of travelling to avoid the heats of summer and cold of winter. It also allows of unlimited outdoor life and affords a generous diet, while good hotels and medical care are also to be found.

PART III.

THERMIC AGENTS.

Thermic agents may be defined as those which are measured by degrees of temperature. When they are brought in contact with other bodies a tendency toward the establishment of a temperature-equilibrium is developed, and the laws which govern this process are the same for animate and inanimate bodies. Animate objects, however, differ in these important respects that, on the one hand, they maintain life only within certain limits of temperature, and, on the other hand, that they possess the power of combating the causes which tend to disturb their normal conditions of body-heat.

All organized structures are destroyed by extremes of temperature; but when properly employed both heat and cold become valuable therapeutic agents.

At present only those comparatively moderate thermic variations which are brought into play in the practice of balneotherapy and hydrotherapy will be considered.

The human body, on account of its constant temperature and unprotected skin, is very sensitive to thermic agents, even if the temperature approaches that of the part to which they are applied; and for this reason general applications produce very marked effects, which are of a stimulating character. The law which regulates this stimulation is that the stimulation or physiological reaction is in direct proportion to the strength of the stimulus or the abruptness of its application. Thus, if we expose a motor nerve and heat or cool it gradually, no reaction—*i. e.*, muscular contraction—is produced, even if the application be continued to complete disorganization of the nerve. But if, on the other hand, a breath of cold or hot air is suddenly directed against a motor nerve, it will be stimulated and a muscular contraction will follow.

The procedures of balneotherapy and hydrotherapy belong to the class of external stimuli which excite local and remote reflex effects

through the mediation of the nervous system. The changes produced are principally vasomotor in character, and manifest themselves locally and at a distance by alterations in the distribution of the blood and in the local circulation, in blood-pressure, in the phenomena of endosmosis and exosmosis, and in the secretory functions, chiefly of the skin and kidneys. An influence may also be exerted upon the respiratory centres, upon the pneumogastric nerves, and upon the body-temperature; whereas, if purely mechanical stimuli are employed, the temperature-variations are nearly always localized and depend exclusively upon modifications in the distribution of the blood.

These powers enable thermic stimuli to exercise a very strong influence upon the nerve-centres, which respond with various phenomena; some of which are readily investigated in the laboratory, while others elude the scientist and are recognizable only by the clinician at the bedside. The clinical results obtained by the use of thermic agents are of great practical importance, and they consist in an exaltation or depression of nervous energy, so that we speak of the effects as *stimulant* or *tonic*, or as *depressant* or *sedative*.

Thermic agents employed in the treatment of disease also possess the peculiarity that, while stimulating the cutaneous nerves, they at the same time convey to or abstract from the economy a certain amount of heat, a feature which separates them sharply from all other modes of peripheral excitation.

Since thermic agents are represented chiefly by air and water, it is important to remember that the former has a very much smaller absorbing power and capacity for heat than the latter. For this reason we are better able to endure variations in the temperature of the air than of water.

The naked body can remain indefinitely in an atmosphere of 90° F., while a bath in the same temperature produces a sense of cold or even a chill. In order that the conditions be equivalent the bath must have a temperature of 104° to 112° F. Conversely, a bath at 115° F. is hotter and of greater influence than an atmosphere of the same temperature; and it is upon these facts that we base our judgment as to the temperature of thermic applications in disease.

Passing on from these theoretical conclusions to their practical application, we find that as the mean peripheral temperature of man is 98.5° F., the temperature of a temperate bath should be 100° F.

Baths having a temperature of less than 90° F. are considered cold; the ordinary cold bath has a temperature of 75° F. (Liebermeister). Hot baths have usually a temperature of from 112° to 120° F., the last being rarely exceeded. Above 120° F. a bath becomes both insupportable and dangerous.

In respect to the temperature of douches, it is important to distinguish between the projection of water in drops and the effect of immersion proper, since, among other differences, the former affects the body-temperature far less than the latter. The classification varies with different authors, but we can well adopt that of Fleury, slightly modified by Beni-Barde, who states that the very cold douche should be 52° to 60°; the cold, 60° to 70°; the cool, 70° to 80°; the temperate, 80° to 90°; the hot, 90° to 100°; the very hot, 100° to 120°.

Here, also, as in the case of the bath, a temperature of 125° is seldom surpassed. It is evident, however, that the water may be colder for the douche than for the bath. In the douche the mass of water is far smaller than in the bath, and the effects of percussion facilitate the reaction of the organism. The duration, moreover, is always brief, and very brief if the water used is very cold. For limited applications the temperature of the water may be very low; and even ice-water may be used.

Hot-air baths are divided into those in which the air is moist and has a temperature varying from 115° to 145°, and those in which the air is dry and the temperature 145° or less, though it may rise to 200° or even higher.

A very important part of the application of thermic agents in disease is the condition of the individual, which is necessarily quite variable and must be carefully noted. Even in health we note appreciable differences in reaction to thermic stimuli, whether these be hot or cold. The differences depend, in the main, upon the state of the circulation, the activity of the sweat-secretion, and the excitability of the nervous system. Sometimes they are the consequences of habits formed in childhood. In disease the variations are more marked and the effects produced are intensified.

By combining different forms of application, as the alternate use of hot and cold water, the addition of mechanical irritation, the degree of stimulation and the intensity of the reaction may be varied within wide limits. The employment of thermic agents in order to secure the best results is an art which, though in a measure depend-

ing upon a knowledge of certain scientific facts, can, in the end, be acquired only by practical experience.

In our description of the practical employment of thermic agents, we shall begin by considering the effects of cold water. For convenience the subject may be divided into two parts—a general description of the effects of cold applications and a description of the special procedures.

The sensations which we perceive at the points touched are specific and distinct from other modes of cutaneous sensation. Physiologists have discovered that there are points on the surface where heat and cold, but not pain, is felt. These are the thermic points of Blix and of Goldscheider. The nerve apparatus of the thermic sense is double; *i. e.*, there are nerve-endings sensitive only to cold, others that respond only to heat (frigorific and calorific points).

According to Herzen, the sensation of cold is, as are tactile impressions, transmitted to the brain by the posterior columns of the spinal cord, while heat-sensations, as well as those of pain, pass upward by the anterior columns. These theories, however, still lack positive proof, and all that is definitely known is the fact that the human skin is very sensitive to temperature-variations, and that the stimulation resulting from such variations is conducted to the central nervous system.

Intense cold lowers the acuteness of cutaneous sensation, and may, therefore, be employed for the production of local anæsthesia. Cold applications of short duration, the water having a temperature of from 50° to 80° F., exalt sensibility, a fact that may be demonstrated by means of the æsthesiometer. At the point of application the skin becomes pale, on account of a vascular spasm, and presents the phenomenon of "goose-flesh," the latter resulting from a constriction of the smooth muscular fibres of the integument. These effects are manifested with a rapidity and intensity proportionate to the strength of the stimulus. At the periphery, below the point of application, the arterioles are contracted, their calibre being reduced to one-half or one-fourth the normal, or even entirely obliterated, a fact that serves to explain the styptic action of cold.

Delmas and Winternitz have shown by the use of the sphygmograph that under the influence of cold applications to the arm or forearm the elevation to which the lever of the instrument rises diminishes as the strength of the thermic stimulus increases. The surface of the part touched becomes cold, since it strives to place

itself in temperature-equilibrium with the water. As, however, animal tissues are bad conductors of heat, and as the subjacent muscles have a tendency to become hyperæmic, the depression of temperature remains localized, neither extending widely upon the surface nor penetrating deeply into the tissues (Esmarch, Schlikoff, Wertheim). Owing, however, to circulatory changes, the temperature falls in the distal regions—*e. g.*, in the palm of the hand—when ice is applied to the forearm, or under the tongue when cold applications are made to the back of the neck. At the same time, and for similar reasons, the volume of the distal parts diminishes, as Francois Frank and Winternitz have shown by the aid of volumnometers. Above the point of application, on account of the obstruction offered by the region subjected to cold, there is an increase in blood-pressure and an augmentation of the activity of the collateral circulation. As a result, a certain degree of collateral hyperæmia is developed which brings about a local rise of temperature. Such an elevation is found to occur in the axilla when cold is applied to the arm, though there is synchronously a sinking of the temperature of the palm.

We may conclude, then, that cold has the power of increasing the vascular tone, either by an action on the muscular coat directly or by stimulation of the peripheral ganglia.

A peculiar phenomenon, first described by Edwards, and known as crossed effect, is that when one's hand is plunged into cold water at 32° F. a thermometer held in the other hand will show a fall of temperature.

Tholozan and Brown-Séquard have made a series of experiments on this subject, using both hot and cold water. When applied to one lower limb the cold water produced a fall, the warm a rise, in the temperature of the other lower limb. In later studies Brown-Séquard and Lombard, by means of the thermo-electric needle, were able to observe similar effects after simple pricking of the skin; and the experiments of Francois Frank and of Winternitz have proved that when cold is applied to one hand the other suffers a diminution in volume.

All these phenomena, the modifications in temperature and in volume, are dependent upon variations in the distribution of the blood.

All the known facts concerning these effects may be summed up as follows:

1. In the course of local applications parts not touched and not homologous suffer a change in the condition of their circulation, which is the reverse of that in the parts subjected to the application; there is, so to speak, a compensatory change.

2. Under the same conditions there is an antagonism between the state of the peripheral and that of the central circulation.

The effect is more intense the more extensive the application of cold. In the cold bath, and even during the cold douche, the peripheral vessels are energetically contracted. The vasomotor system, reacting to the reflex stimulation, opposes a barrier to the abstraction of heat by restraining the conveyance of the blood to the surface. It is at that moment that the skin grows pale and assumes the "goose-flesh" character. At the same time the internal organs become congested from vaso-dilatation. This is not solely due to a compensatory action, but, as we shall soon see, depends also, when the applications are somewhat extensive, upon disturbances of thermogenesis. The contraction of the cutaneous vessels under the application of cold leads to an increase in the rapidity of the current and an elevation of the pressure of the blood. This has been proved both by the use of the sphygmograph by Delmas and Winternitz, and by the apparatus of von Basch.

It is very probable that the blood-pressure rises very markedly under the influence of cold applications, notwithstanding the compensation due to central vaso-dilatation. Since the time of Howard F. Johnson (1852) all advocates of hydrotherapy are in accord in stating that cold applications modify the action of the heart (Fleury, Bence Jones and Dickinson, Scharlau, Petri, Delmas, Winternitz, and others), the changes being analogous to those produced by painful stimuli (Naumann, Rohrig, Frank), and the principal facts that have been developed in this connection may be expressed as follows:

A localized peripheral irritation, mild in character, such as is produced by the application of ice to the arm, is without influence upon the heart.

A more energetic, but still limited, application may or may not produce an effect.

When the application is general the contractions of the heart immediately become precipitous and irregular. Slowing never occurs in the beginning. The large cold douche influences the heart more energetically than any other procedure. During its continuance the pulse becomes filiform and irregular; and at times there is in the

beginning a transient tetanic state of the heart, which causes a momentary disappearance of the pulse (Delmas). A somewhat violent and prolonged douche may induce collapse and syncope.

The rapidity of the heart increases *pari passu* with the elevation of arterial pressure under cold applications, constituting an exception to Marey's law, that the pulse becomes slowed in proportion as the pressure rises.

Partial applications exert no influence upon respiration, but extended applications render the respirations irregular and jerky; the douche may in the beginning produce a sense of oppression and anxiety.

The temperature-changes are of considerable interest. In spite of the physiological mechanism, the activity of which maintains the bodily temperature, the thermic regulation of the human economy is not perfect.

Every abstraction of heat, whether great or small, is followed by a fall of the internal temperature, although this is not immediately felt. During the action of the application the variations in temperature depend, as has been stated above, upon the intensity and extent of the applications. As we have seen, cold applications of limited extent cool the part they touch and warm the neighboring regions; they may also have a crossed effect. Edwards held that the fall of temperature in the opposite limb was due to a cooling of the blood. This is not the case. It is best explained by a reflex action, under the influence of which the afflux of blood to the part diminishes.

In order to influence the central temperature Leube estimates that a cold application must cover at least a third of the cutaneous surface. A general application, even if brief in its duration, always reduces the temperature. Occasionally, while the variations in the temperature of the superficial and intermediate zone of the body are quite marked, those in the central zone are very slight, particularly in the healthy, non-febrile subject. During fever the central temperature is more easily modified, since the thermic centres are then comparatively weak and impressionable. The studies of Delmas, Liebermeister, Winternitz, Aubert, and Couette enable us to formulate a general law, which may be stated as follows:

Under the application of cold to the general surface a tendency is manifested, in spite of the physical withdrawal of heat, to an elevation of temperature in the intermediate and, at times, in the cen-

tral zone of the body. An immediate reduction of temperature is rarely observed; only exceptional conditions of cooling by powerful and rapid measures bring about this result.

The tendency of the body is to consume its heat by contracting the peripheral capillaries and thereby preventing the blood from leaving the central and warm portions of the body. In disease, however, we may find it necessary to produce a prompt depression of the temperature by causing dilatation of the peripheral vessels by means of mechanical manœuvres, such as friction, which causes an increase in the loss of heat through the skin through increased circulation.

The course of the fall in temperature in the full bath is retarded by corpulence and by voluntary movements (Senator, Liebermiester, etc.), and for the reasons just given it sets in earlier if cutaneous friction is practised (Winternitz).

The influence of cold applications on blood-flow, blood-pressure, and the temperature may be summarized as follows:

Distribution of blood	Contraction of the peripheral, dilatation of the central vascular network.
Blood-pressure	Increased by the general application of cold, despite the compensatory vaso-dilatation.
State of the heart	Acceleration; irregularity.
Temperature	Elevation of temperature in the intermediate zones. No change or a rise in central temperature. Fall if application is prolonged or very intense.

It is now proper to take up the secondary phenomena produced by the applications of thermic agents. In a general way it may be said that all the phenomena that are primarily excited by cold applications are followed by others of an inverse type. When the applications are of moderate degree and short in duration, the secondary changes manifest themselves only upon the cessation of the stimulation. When the application is prolonged, some of these phenomena supervene during its continuance and become accentuated after its termination.

These secondary or post-operative effects constitute the real effects; they are the therapeutic end which we desire and for which we strive. They correspond to that which writers on hydrotherapy have designated as the *hydrotherapeutic reaction.* The significance of this term is, however, not identical among authors. Fleury, one of the first to call attention to it, designated by the term the return of the blood to

the periphery—*i. e.*, the circulatory reaction. Beni-Barde applies the word to the spontaneous or induced return of the heat to the limbs; with him it is the thermic reaction accompanying the return of the blood. An analogous thought is expressed by Scheuer, who considers as the reaction the establishment of a normal thermic condition about the extremities of the nerves.

As the return of the peripheral warmth has not the same physiological importance as the fluctuations of the central temperature, other authors, among them Aubert and Bottey, prefer to express by the word "reaction" the general course of the central temperature. Couette finally has considered the question from another point of view, and considers the reaction to be the struggle of the system against the cold, expressing itself in an increased activity of nutrition and combustion.

Taking up now the secondary phenomena individually, we find that after the local application has been terminated the constriction of the vessels ceases and a dilatation takes its place. The contraction is brisk, but the relaxation is slow and gradual; the skin becomes red, the goose-flesh vanishes, the temperature rises progressively. For a long time, however, a certain degree of stasis of the blood, and probably of the lymph, remains.

Analogous changes take place in the deeper parts. If the application of cold has been very intense, a loss of tonicity of the cutaneous and even the deeper vessels may result, and if the relaxation is prolonged so that permanent stasis is threatened we resort to mechanical stimulation in the form of friction as one of the most efficient means of favoring the return of the blood to the periphery.

When the douche is employed in place of the bath the secondary changes in the blood-pressure and in the condition of the health are somewhat different from those first described. As soon as the patient begins to dress the pulse diminishes in frequency, often sinking below the initial number, while arterial tension remains elevated. Later, however, the pressure falls likewise, but the slightest impression of cold at this time is capable of again raising it. Gradually the pulse gains its normal characters. The minima of pulse and tension, as well as the maxima, generally correspond (Delmas). This indicates that under the condition in question, contrary to what obtains ordinarily, there exists a sort of independence between the heart and the vessels.

The modifications in the distribution of the blood at the periphery

of the body are, as has been stated, accompanied by changes of a reverse character in the deep circulation.

The preliminary central vaso-dilatation is replaced by a vaso-constriction, which leads to anæmia of the internal organs. Francois Frank, in his recent studies on revulsives, has obtained from the beginning a vaso-constriction of the deeper parts and a general vaso-dilatation elsewhere.

Many theories have been advanced to explain the cardiac changes, but none are satisfactory ; it is, therefore, not necessary to dwell upon them.

The irregular respiratory movements previously referred to are succeeded by deeper and less rapid movements during the existence of the secondary effects. (Rohrig, L. Lehmann.)

The most important, however, of the secondary changes, are those occurring in the body-temperature. They have been so thoroughly studied that we can speak with considerable precision upon them.

After local applications the return of heat to the periphery takes place slowly and gradually, *pari-passu* with the restoration of the normal circulation. In the case of general applications, the changes of the central temperature, which are the most important, follow a variable course, according to circumstances.

The central temperature declines in the period during which the blood is returning to the periphery and while the arterial tension is falling; afterward it rises to the normal in a gradual manner.

It is noteworthy that it is during the period of temperature-fall that the patients experience the sensation of comfort which accompanies the hydrotherapeutic reaction, and which appears to be due to the return of the blood and warmth to the periphery of the body.

The course of the changes following a cold application is affected especially by repose, by exercise, and by mechanical stimuli.

Exercise hastens the occurrence of the secondary phenomena ; it causes a diminution in the pulse-rate, lowers the central temperature, and at the same time raises arterial tension. Friction after the application acts in the same manner. Exercise or friction before the use of the douche exaggerates the intensity of the reaction.

For the thorough understanding of the uses of cold in treatment it is necessary that the physician understand not only the effects produced on the nervous and circulatory systems, but also those which manifest themselves in the body-temperature, particularly in its relation to tissue-waste.

Many careful researches have been made as to these points after two methods. In the one the loss of heat has been ascertained by means of the calorimeter; in the other, the so-called indirect method, the products of combustion are determined.

Calorimetric measurements are not altogether trustworthy. The indirect method is also open to reproach, but is that adopted by the best physiologists, who have attempted to solve the problem simply by calculating the respiratory combustion; that is, determining the amount of oxygen consumed and of carbon dioxide excreted. This method, however, yields only a fraction of the total, but a fraction which is very important and readily obtained under varying conditions.

The fact has been determined by many investigations that in warm-blooded animals cold increases the consumption of oxygen.

Among the most recent experiments, those made by Fredericq upon himself are worthy of the greatest confidence. They were made by means of an apparatus similar to that of Reynolds and Reisch. A condition of cold was obtained simply by disrobing the body. A number of experiments were made for the purpose of determining the influence of various causes, especially the action of food. The author constantly found an increase in the consumption of oxygen corresponding to the intensity of cold, or, rather, to that of the subjective sensation of cold at the periphery of the body.

The action produced by cold during the course of digestion is insignificant on account of the great production of heat by the activity of the glands. During fasting the production of heat is insufficient, and if the individual remains at rest the internal temperature falls.

Similar results were obtained by Fredericq in experiments upon the rabbit. The projection of cold water against the body of the animal led to an augmented consumption of oxygen and an increase in the excretion of carbon dioxide.

The conclusions of Fredericq have been confirmed by others. A. Loewy and Zuntz have proved that the increase in thermogenesis under the influence of cold does not, in man, rise in any constant manner. In the human subject the skin appears to be the principal and sometimes the only instrument of thermic regulation. Nevertheless the existence in man and warm-blooded animals of a regulating apparatus which modifies thermogenesis and becomes active under certain conditions is now generally accepted. The centres

of this apparatus are situated in the spinal cord and brain, and their action is to maintain the tone and energy of interstitial oxidation. Section of the spinal cord near the medulla causes a progressive fall of temperature, which transforms certain species of warm-blooded animals into cold-blooded animals. The excitation of the centres by puncture (Heidenheim) or by electricity (Fredericq) increases the intensity of tissue-combustion. The centres are reflex, not automatic in action. Fredericq's experiments leave no doubt upon this point. Thus the inspiration of cold air, even the deglutition of ice, leads to the internal cooling and a diminution in oxidation. An increase in oxidation only results from an action of the cold on the sensory nerves of the skin. The mechanism is reflex, like that of the vasomotor centre which governs the distribution of the blood.

The seat of the increased oxidation under exposure to cold is in the muscles. This has been abundantly proved. Localized cold applications produce an increase in the tonic state of the muscles, not only *in situ*, but also at a distance. During extensive applications, as in the case of the bath or the douche, the patients frequently shiver or are seized with a distinct chill. The cold bath, with the water at a temperature of from 68° to 77° F., generally produces an immediate but not intense chilling; then, after a variable period, a second and more pronounced chill supervenes; it soon passes into a tremor and is an indication of the onset of danger. The application should always be suspended before the appearance or immediately on the beginning of this second chill. After a very cold or prolonged bath the chill persists for a certain period of time. According to the experiments of Loewy and of Zuntz, the increase in the consumption of oxygen is dependent upon the manipulations on the part of the muscular system. When the cold applications were neither too intense nor too prolonged, some of the subjects experimented on remained quiet and did not shiver nor tremble with chill; in them the consumption of oxygen was not augmented. Speck has pointed out the relation of oxygen-consumption to voluntary movement.

When cold applications of moderate degree are supported without the production of augmented consumption of oxygen, the fall in the central temperature either does not occur at all or is very slight. In these cases the thermic regulating apparatus located in the cutaneous network is perfect or almost perfect. Although there is under

these conditions an inevitable abstraction of heat, yet the changes in the distribution of the blood in the skin are able to restrict the loss, and even to determine a certain degree of retention of caloric, to which we must ascribe the initial rise in the central temperature, in the absence of a sensible increase of oxidation.

In summing up this part of the subject, we may say that in man and other animals possessing a constant temperature, the resistance to cold depends upon a diminution in the cutaneous radiation, as well as in an increase in the production of heat. In man, whose integument is naked and sensitive, the chief factor is the restriction of loss through the skin.

The action of cold extends also to the unstriped muscles innervated by the sympathetic nerves. The application of cold compresses to the abdomen or the cold douche to the hypogastrium produces a contraction of the bladder, and, likewise, a cold foot-bath causes contraction of the uterus.

The action of cold on the cutaneous functions proper, the secretion of sweat and perspiration, is as yet but little known. According to Röhrig, perspiration is diminished by a fall of the temperature of the skin. But it is possible, though not yet proved, that it may be increased after the return of the blood and the peripheral warmth.

As for the sweat,[1] it appears to be well established that cold applications lessen its secretion. Diuresis, on the contrary, is promoted, although it is necessary not to confound this with the mechanical evacuation of the bladder by reflex contraction.

An increase in the quantity of urine has been proved to exist by Müller, in Claude Bernard's laboratory, and was by him ascribed to renal hyperæmia. It manifests itself ten minutes after the application, and the urine passed may contain a trace of albumin. Hydrotherapy is capable of increasing, under certain conditions, the so-called physiological albuminuria.

Cold also produces an increase in the intestinal secretions, although the anticonstipating effect of cold applications may sometimes be as well explained by reflex contraction of the intestines as by augmented secretion.

Refrigerating applications are frequently combined with mechanical procedures. The combined effects have been particularly studied by Winternitz. The mechanical stimulus may be a part of the

[1] By perspiration the author evidently refers to what we call imperceptible perspiration in distinction from sweat.—Ed.

thermic agent itself, as the pressure of the water, or may take the form of friction, massage, etc.

The pressure of water is not exactly measurable, since during an application it is constantly subject to changing conditions. It may be graduated, however, with sufficient accuracy for practical purposes.

Pressure impedes muscular movement and may interfere with respiration when the application is made to the upper part of the trunk.

In driving back mechanically the blood contained in the skin, the pressure contributes to the production of cutaneous anæmia, and also renders the subsequent vaso-dilatation more easy. The effects remain superficial if the water is not in motion; but extends to the deeper tissues, by virtue of a sort of massage of the muscles, if the stream is large and the pressure high, and the employment of a strong pressure and of the unbroken jet may be followed by fatigue and exhaustion, even when the application is brief.

Diverse experiments have shown that friction increases in a considerable degree the loss of water through the skin. According to Weisroch, the augmentation may, with light friction, amount to 50 per cent. But the most prominent effect of friction during the use of cold consists in an increased loss of heat. This loss has been measured by means of partial calorimetry. Popischil found that moist and cold friction, limited in extent, increases the loss of heat 80 per cent., while cold douches, followed by exercise, augmented it 67 per cent., and observations of Liebermeister and of Winternitz illustrate the practical importance which is attached to these mechanical means, especially when employed in antipyretic medication.

When friction is made with sufficient energy it altogether prevents the appearance of chill by augmenting the fall of the central temperature, and it plays an important *rôle* in cases in which it is necessary to abstract a large quantity of caloric.

Remote effects are sometimes produced by cold applications. These phenomena are only known through observation on the sick, since they almost entirely elude experimental study. They possess no less interest, however, for it is in reality the late effects which we desire to obtain by our treatment. Among them is a modification in temperature, which may become an inconvenient feature in the use of cold applications.

Occasionally the fall of the central temperature is succeeded, as a

late effect, by a temperature-rise. This augmentation of temperature, which constitutes what has been termed the counter-reaction, is the rule in fever patients subjected to cold bathing; Winternitz and Jurgensen claim that it may also be observed in non-febrile cases. Its occurrence seems to depend on diverse individual and external circumstances. Yet it is very rare after properly conducted hydrotherapeutic measures. Several writers have observed in the application of hydrotherapy the development of a pseudo-febrile state, a form of transient crisis which terminates in abundant sweats and a furunculous eruption, and which presents a certain analogy to the so-called thermal crisis. This crisis was formerly considered salutary, and it was customary to strive for its production. It seems almost exclusively to follow the abuse of hydrotherapeutic methods, but occurs rarely when these are rationally and intelligently applied.

The most important late effects are those upon the general nutrition.

Cold, as has been intimated, tends to increase the consumption of the hydrocarbons contained in the muscles. This action, however, is transient and even inconstant, and cold in this respect is inferior to other agencies, such as exercise, food, etc. (See Fredericq and others.)

The hydrotherapeutic measures also influence the oxidation of albuminous principles, and thus bring about a change in the urine. Kirejeff has recorded an increase in the excretion of urea, uric acid, and chlorides. Others have found a diminution in the uric acid and the phosphates. But the variations are neither constant nor marked.

Sometimes the weight of the patients indicates that nutrition has been deeply affected. Often there is an increase in weight, as in 56 out of 100 cases observed by Winternitz. This fact does not accord with the theory of decreased assimilation. But it is essential to note that the observation concerns sick persons who are not placed under an identical and unvarying *régime*; the increase in them consequently is due to an improvement in the appetite as well as to a stimulation of the majority of the functions capable of bringing about a better general condition.

It may, then, be definitely asserted that hydrotherapy safely conducted is favorable to the re-establishment of the equilibrium of the important functions.

The majority of patients treated at establishments speedily become cheerful and develop a desire for muscular exercise.

Usually, with the amelioration of the general state of the health, the sleep becomes more regular, more profound, and more refreshing.

Another of the remote benefits of the treatment which deserves mention is the diminished sensitiveness to cold. There are probably great individual differences in respect to the loss of heat by the skin. Researches are wanting on this subject, but we may readily take cognizance of these differences by noting the variability of the sensations which we ourselves experience in our contact with the skin of different persons. Thus certain individuals, generally those somewhat obese, have always a cool or even cold skin, while in lean persons the skin is usually warm. In the first class of subjects hydrotherapy is able to increase the loss of heat by stimulating more or less permanently the languishing cutaneous circulation. As this may conduce to a loss of flesh, the hydrotherapeutic treatment may be employed as a means of treating obesity.

In the other class of persons the hydrotherapeutic methods restrain the loss of heat by increasing the tonic state of the cutaneous vessels and bringing about a modification in internal oxidation. Under these circumstances hydrotherapy leads to stoutness.

From what has been said it follows that repeated stimulation of the thermic regulatory apparatus is capable of modifying favorably many vices of general nutrition. But to secure such a result it is requisite that the heart and vessels, the respiratory and digestive organs, possess a certain degree of vigor. Young persons profit especially by cold applications, since they possess a nervous system that reacts promptly, and organs that are not altered structurally to any degree. In those in whom heart and vessels are degenerated the treatment must be most gentle and must be applied with great circumspection. The same is true in the case of those whose nutrition is poor, and whose nervous system is feeble, as in the aged, the extreme young, the profoundly anæmic, and the neurasthenic of certain types.

Employment of Cold Internally. Cold is of use internally. Cold water may be drunk even during the course of the applications or in their stead. Sometimes also injections of cold water are employed. The effect of these have been investigated by Lichtenfels, Fröhlich, Liebermeister, and Winternitz.

According to the same authority, a rectal injection of a litre of cold water lowers the temperature of the stomach 1° (0.9°), that of the rectum 1.5°. Sphygmographic tracings taken during these experiments indicate an increase in arterial tension.

According to Fredericq, the inspiration of cold air or the swallowing of ice is followed by a reduction in respiratory combustion.

Rectal injections of cold water have been employed for combating pyrexia by many physicians, notably Foltz, of Strasburg, but its external use is more wise.

Cold applications also act upon the secretion of the bile, and Bidder and Schmidt, Nasse, Lehmann, and Röhrig have noted an increase in the quantity under their influences. Perhaps this is simply due to a reflex contraction of the gall-bladder. In any case, it is on the strength of this effect that rectal injections have been suggested in the treatment of catarrhal jaundice.

Cold applications may be made by means of spiral coils, through which cold water is made to flow, and by ice-bags. The coils possess the advantage that they may be given any hour, and that they prevent the heating of the parts to which they are applied. They are generally made of rubber, and may or may not be covered with linen.

Sometimes cold cushions, through which water is allowed to flow, are substituted for the coils. Among other forms of apparatus constructed on the principle of the coils, mention may be made of the belt of Dumontpallier and Galante, the use of which seems to have been abandoned; the refrigerating bonnet and others.

Ice-bags are made of bladders or of rubber sacs; those of Chapman, intended for application to the spinal region, are most commonly employed. The vaginal ice-bag should also be mentioned.

The cold sound is a double catheter, without fenestra (Winternitz), possessing an afferent and efferent tube. The end of the sound is passed as far as the neck of the bladder; water of 50° to 60° is then allowed to circulate through the sound for from eight to twelve minutes. It is often better, however, to begin with warmer water, 62° to 66°, and then cool it gradually. Burgonzio has found the cold sound useful in seminal emissions and in impotence.

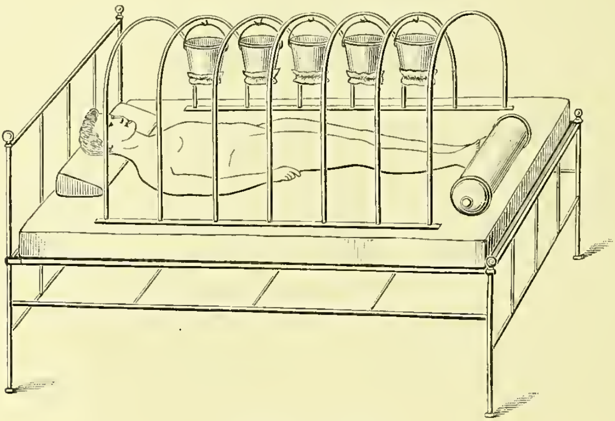
Atzperger has designed a similar metallic tampon for the purpose of conveying cold to the rectum, as a means of treating hemorrhoids and prostatic congestion.

A few words may with propriety be devoted to the use of air as a means of lowering temperature.

By means of its physical properties air does not possess the power of abstracting heat to any marked degree. The effects of air-baths have been studied by Kaczarowski (1879) and by Traubenberg (1883).

More recently the subject has been revived by Soltau Fenwick, of London, who has devised an ice-cradle. The apparatus consists of five or six hoops resting with their bases upon the bed. From the centre of the curve of each hoop hangs a bucket half-filled with ice. Each bucket is covered to prevent dripping, and a light cover is thrown over the hoops. The patient, protected by a thin, non-transparent muslin cover, and with hot-water can at his feet, is surrounded by a cold atmosphere. The air should circulate freely about the bed. By this method the temperature of the atmosphere is lowered only one or two degrees. Nevertheless, a chill may sometimes occur or

FIG. 9.



Fenwick's Air-bath.

the body-temperature may fall below 101°. In either case the application is suspended. Quite often it has been found necessary to keep typhoid patients in the ice-cradle for ten to fourteen consecutive hours.

Mention should also be made of the air-douche of Dupont (1884), in which douches of compressed air are administered. The air is obtained from the tubes in connection with the pneumatic clocks that are in use in Paris. The expansion of this air produces quite a high degree of cold, while the current of air striking the body produces a form of percussion.

Since the heat-capacity of air is much less than that of water, the procedure is more analogous to massage than to the cold douche. Dupont states that he has observed stimulation of deep muscles, as of the stomach, when the air-douche is applied to the epigastrium.

He does not allude to the temperature-changes. The skin at the seat of application becomes red, and the patient experiences a sense of peripheral warmth.

Hot Applications.

Physiological Effects. The effects of hot applications are not, as it might at first appear, the reverse of cold applications; there are certain analogies between them, but also pronounced differences. The latter depend chiefly upon the fact that heat brings into play a physiological mechanism differing from that called into action by cold. The analogies are in the mode of application, as both are essentially external means. Sometimes heat and cold are employed in combination or alternately. The physiological effects are such that it is advantageous to point out briefly the distinctions between hot and cold hydrotherapy.

The stimulation of the cutaneous thermic nerves by heat produces local phenomena which are in part reflex, and, therefore, analogous to those excited by cold. Then there is at first vaso-constriction, such as follows any form of stimulation; it is more marked the more accentuated the difference between the temperature of the thermic agent and that of the skin. But while the vaso-constriction due to cold tends to persist, that following a hot application is transient and is soon followed by a vaso-dilatation, which continues as long as the application lasts. When the temperature of hot water is moderate (about 100° F.) the tactile sensibility is rendered more acute; when the temperature is 120°–126° the sensibility is dulled, as it is by intense cold. As a characteristic accompaniment of the vaso-dilatation we have sweating.

The effects of hot applications on remote portions of the body are less marked than those following the use of cold, but they are subject to the same general laws, particularly as regards the crossed effect and the compensatory phenomena. Thus the experiments of Brown-Séquard and Tholozan have shown that the warming of a hand or a foot produces vaso-dilatation and congestion in the homologous part. On the other hand, it has been observed by Winternitz that a sitz-bath at 112° F. produces a compensatory diminution in the volume of the arm, whilst cold, as stated on a previous page, produces an increase in volume. The sweat-secretion also obeys the law of crossed effect. In one of his experiments Adamkiewicz applied a vessel

filled with water at 122° to a man's thigh, and noted congestion of the limb and sweating of the foot, and the other limb began to sweat at the same time.

When the hot applications are localized and brief in duration they modify neither the general circulation nor the heat-production. Increased warmth is found only in the parts touched and in those the seat of a reflex vaso-dilatation. When the applications are more widespread general reactions are produced.

Regarding the changes in the distribution of the blood under the effects of heat, Mosso and Bergesio, in their experiments upon the cerebral circulation in man, have found that during a hot foot-bath the vessels of the brain at first are dilated, the current is slowed, and the veins become congested—these changes corresponding to a constriction of the peripheral arteries. Soon cutaneous vaso-dilatation sets in, and synchronously with it the cerebral congestion gives place to anæmia. These modifications are naturally more intense in the case of a general hot bath. Similar observations have been made by Schüller upon trephined animals. It is highly probable that analogous changes take place in other internal organs; these facts also offer an explanation of the debility and tendency to syncope which develop in the course of energetic and prolonged hot applications.

In certain regions of the body the circulatory changes are peculiar and differ from those just described. Thus it has been found by Katzaurow that during a hot pediluvium, or hot bath, the eye presents first a condition of anæmia, which is followed by an intense congestion. The ocular changes correspond in character with those of the peripheral zone of the body.

The majority of authors note an increase in blood-pressure under heat, due to a compensation of the peripheral vaso-dilatation by constriction of the deeper vessels. L. Lehmann found the pressure increased in hot as well as in cold baths. Grefberg, in experiments on curarized dogs, observed a rise in tension during the bath at 122°. Schüller, in studies upon rabbits, obtained only a brief rise, followed by an abrupt fall.

Action on the Heart. The effect upon the heart varies with the intensity of the application. In general the pulse-rate falls slightly during the first stage of the circulatory changes, and rises in the second (Mosso, Bergesio, and others). Very hot applications cause, according to Schüller, an immediate slowing of the heart. Winter-

nitz observed the same phenomena during the use of partial hot applications. In the case of general applications the effect seems to be different. Thus, Poitevin states that a hot bath at 114° is without influence upon the heart. Above 114° there is an acceleration of the pulse, which amounts to 41 pulsations in a bath of 120°.

The specific effects of hot applications express themselves chiefly in changes in the sweat-secretion, in changes in respiration and temperature. The sweating may be local or general, the latter especially when the applications act upon particular surfaces, as in the pediluvium. The effects of the full bath, the douche, the vapor, and the dry-air bath are variable, and will be discussed in a subsequent chapter.

Localized applications, if sufficiently intense, produce an acceleration of the respiratory movements. Winternitz obtained this result by applying water at 144° to the chest or the back of the neck. Sometimes in therapeutic applications the respiration is not influenced unless the application is general. The acceleration of the respiration, which is sometimes known as heat-dyspnœa, varies largely with the nature of the means employed. The force of the respiratory movements is lessened by baths, the temperature of which exceeds that of the body (Stolnikoff), and increased by tepid baths (Groedel).

The changes in the temperature depend to a large extent upon the means employed. General heat applications cause a more or less rapid rise in the central temperature from 1° to 4° in a bath at 110°, in spite of the inspiration of cold air (Liebermeister). Partial applications, by exciting the sweat secretion, can effect a fall in the central temperature. Thus a hot pediluvium produces, according to Shokowski, an elevation of temperature in the external auditory canal (peripheral zone of the body) and a depression of the rectal temperature.

In its struggle against heat the organism can only avail itself of processes which augment the loss of heat. Heating of the body produces in man as well as in animals an increase in respiratory combustion, a fact fully established by the researches of Voit, Page, Fredericq, Pflüger, and others. The means of heat-dissipation upon which the system relies are the production of sweat, the evaporation from the lungs, and the increased loss of heat from the skin by a heightened activity of the peripheral circulation. The cooling action which results from the evaporation of sweat has been studied experi-

mentally by Benjamin Franklin, Blagden, Delaroche, Beger, and others. The importance of sweat-evaporation may be more readily estimated when it is recalled that the amount of heat required to vaporize one grain of water is capable of raising the temperature of 580 grammes of water from 0° to 1°. The greater part of the sweat remains in the liquid state, and this is fortunate, for, were all of it vaporized, the abstraction of heat would be enormous and harmful. The important relation of the sweat-secretion to the regulation of body-temperature has been especially made known through the contemporaneous writings of Luchsinger, Adamkiewicz, Vulpian, and Nawrocki.

They have shown that the secretion is controlled by centres disposed along the spinal cord, which in turn are governed by a higher centre in the medulla oblongata. Fibres arise in the spinal centres and pass out through the anterior roots, to terminate in the sudoriferous glands. The governing centres are automatic in their action—that is, their activity depends upon the temperature of the blood.

Luchsinger made a series of experiments on sweat-secretion upon cats. Having cut the spinal cord transversely and divided the posterior spinal roots, he placed the animal in a hot room, and found that it became covered with sweat. The inspiration of hot air and the ingestion of hot liquids produced the same effect. The medullary centre, as Adamkiewicz has shown, can also be excited by electricity.

The same observer has shown that sweating may be produced by reflex stimulation; but the automatic action is far more important. The sweating following hot applications made for therapeutic purposes is in proportion to the general heating of the body.

The second means of resistance against overheating is represented by the peripheral vaso-dilatation. The hyperæmia at the point of application necessarily contributes to and favors a heating of the blood, but there is simultaneously vaso-dilatation at a distance, which persists and constitutes an important safeguard. The dilatation is partly reflex, partly automatic in origin.

Finally, the third means of defence is the increased evaporation from the lungs, resulting from the acceleration of the respiratory movements. The heat-dyspnœa investigated by Bernard and by Ackermann is the result of the action of an automatic mechanism, the respiratory centres, as demonstrated by the experiments of Gold-

stein, Fick, Gad, Martschinsky, and others, being strongly influenced by the temperature of the blood. The elevation of the temperature need not be great to produce an acceleration of the respiratory movements. The circulation of water at 104° about the carotid arteries suffices, according to Goldstein and Fick, to produce heat-dyspnœa. Bonnal, in a recent paper, has shown that the acceleration of the pulse and temperature may be manifest in the dry chamber and in the hot bath at 116° before an elevation of the central temperature is demonstrable.

The facts so far developed permit us to conclude that heat acts especially on the automatic, cold on the reflex mechanism.

Hot applications, unlike those of cold, are not followed by any reaction. The principal effects produced by hot applications persist for a time after the cessation of the applications, but eventually pass off and give place to the initial conditions. This is true of the external vaso-dilatation and the anæmia of the deeper organs, both of which phenomena gradually disappear as the nervous system relaxes, owing to the return of the temperature of the blood to the normal. For these reasons it is essential that whenever a strong effect is desired, the means employed should be capable of producing a distinct heating of the body. This power is not possessed by the temperate or even moderately warm bath, inasmuch as the evaporation of the water which adheres to the skin after emergence from the bath tends to abstract heat and produce a fall of temperature.

The changes in the pulse and the blood-tension persist for a variable period of time. Durian has counted an increase of 90 pulsations in the dog following the use of the hot bath. At Toplitz the acceleration of the pulse is still perceptible sixteen hours after the hot sitz-bath in use there. As regards the arterial tension, it is probable that in those cases where a primary increase is noted, the decline to normal is rapid. According to Schüller, the slightest initial rise is followed by a marked fall, which in turn is succeeded by a trifling and momentary rise before the final return to normal.

The modifications in sweat-secretion vary with the nature of the procedures employed. Bonnal states that the active perspiration which occurs during the hot-air bath at 131° ceases as soon as the patient leaves the chamber, whilst it is, on the contrary, very profuse after the hot-water bath at 116° and after the vapor-bath, both of which restrain sweating during their application.

Below we give in a tabular form the principal effects of hot applications:

Distribution of the blood.	Peripheral vaso-dilatation; central anæmia.
Arterial tension.	At first increased, then diminished.
Heart.	Transient slowing, then acceleration, or acceleration from the beginning.
Central temperature	Increased.
Sweating	Strongly stimulated.
Respiratory movements	Accelerated.

To complete our study, it is necessary to give a brief description of the effects produced on the secretions, the muscles, the nervous system, and on general nutrition.

The application of heat impresses the secretions more markedly than the application of cold. According to Röhrig, the insensible perspiration is excited simultaneously with the secretion of sweat. The combined effects result in a tendency to dehydration of the organism and to a loss of sodium chloride. In consequence of this the other secretions, notably the urinary and intestinal, are diminished. Constipation may be produced, a fact that may elucidate the beneficial action of certain thermal cures in the treatment of chronic diarrhœa.

The muscular system is not influenced by heat to the same extent as by cold. Experience has, however, demonstrated the hæmostatic value of hot applications, an effect generally ascribed to reflex action, through the intervention of the sympathetic motor nerves. An example commonly cited is the arrest of internal hemorrhage by the application of heat to the loins. But the question is obscure, for we see that hot sitz-baths, especially if a little mustard is added, instead of causing anæmia, determine an intense congestion of the pelvic organs. On the other hand, the general bath, temperate rather than hot, but sufficiently prolonged, seems to cause a relaxation of muscular structures in deep organs, if we may judge from the benefit obtained from it in the treatment of hepatic and nephritic colic.

The depressing action of heat presents a striking contrast to the thermic effect of cold applications. When the means employed are gentle and insufficient to excite the defensive mechanism against heat, there is produced a diminution in the irritability of the nervous system—a sedative effect which appears to be, as Traube has thought,

the result of the removal for a certain time of external stimuli from the sensory nerves.

When sufficient heat is applied to induce an elevation of the temperature of the blood, the nervous system suffers a sort of shock, which is followed by a distinct sense of fatigue. The moderately hot douche, with water from 100° to 110°, although producing a slight elevation of the central temperature, constitutes a powerful means of depression. The tepid bath has the same influence. Fatigue and exhaustion are effects of more energetic procedures, such as the hot bath and the vapor-bath, which produce a more marked elevation of temperature, and at the same time a profuse diaphoresis. A tendency to sleep may also follow.

Hot applications act more energetically than cold upon the processes of nutrition. Bartels, in 1864, noted in man an increase in the excretion of urea after vapor-baths; Naunyn has observed the same fact in dogs. G. Schleich found an increase of 29 per cent. in the excretion of urea in persons living under a uniform regimen and taking baths lasting an hour at a temperature of 104° to 108°. This azoturia persisted for several days after the cessation of the use of baths. A. Frey and Heiligenthal have obtained different results. They found a diminution in urea-excretion under the use both of the hot-air and the vapor-bath, but a great increase in the elimination of uric acid. The question, therefore, cannot be considered as definitely settled, and further study is necessary.

PART IV.

HYDROTHERAPEUTIC MEASURES.

HYDROTHERAPEUTIC procedures are divided into the simple, in which only one hot or cold application is made, and the compound or mixed.

In beginning the study of the procedures in which cold is employed, it is well to discuss briefly certain general precautions which the use of these means imposes upon us.

Care should be taken to prevent chilling and to secure the proper development of the secondary or post-operative effects which constitute the reaction.

It is necessary before applying cold to the surface of the body that the patient be under normal conditions as regards the distribution of temperature. Sometimes he is prepared for the procedure by mild friction, or by making him take a moderate amount of exercise.

The room should have a suitable temperature, from 70° to 74°. As regards the preferable time, it is best to make the application at the moment of rising, or at least in the morning, in order to secure a speedy and vigorous reaction. The application should not be made immediately after a repast nor just before retiring at night.

The douche and the full bath, being employed to produce an intense cooling, should be of short duration and should be interrupted at the appearance of the second or great chill. When it is necessary to produce a powerful cooling effect, the development of the chill is delayed by means of movements or by practising friction. It is the rule to permit an interval of several hours to elapse between two applications in order that the organism may remain in a normal equilibrium for a sufficient length of time. At most two applications, separated by a space of from six to eight hours, are made in a day, save when it is necessary to combat fever. In every case the return of the peripheral warmth should be secured after each appli-

cation. It may be incited by exercise, by friction, by warm clothing, etc.

Whenever, during the employment of cold, a tendency to collapse develops in spite of the observance of the precautions just given, resort should at once be had to spirituous drinks, or even to the immersion in a hot bath.

It is a useful provision to take note at the commencement of the treatment of the impressionability of the individual and his power of reacting from cold applications.

Whether we use cold or heat in hydrotherapeutics, however, we distinguish procedures with percussion from those without percussion. The type of cold applications combined with percussion is the douche, the hydrotherapeutic agent which, beyond doubt, occupies the first place.

Douches. In the case of the *general douche*, it should be administered with water, the temperature and the force of projection of which can be varied at will. The principal varieties of douches are: the shower-douche, the column-douche, the douche of concentric layers, the sheet-douche, the circle-douche, and the movable-jet douche.

The management of the douche-chamber and its appurtenances should leave nothing to be desired. Under the douche, within reach of the patient, supports should be arranged for the arms, which will be useful in case of respiratory embarrassment; means should also be provided for a foot-bath before the douche, if the procedure is deemed necessary.

In the beginning of the treatment, cool water, at a temperature of from 66° to 74° F., is employed, and a low pressure equal to about seven pounds. Later the temperature of the water may be at 60°, then 55°, and rarely even as low as 50°.

At the commencement the duration of the douche is only twelve to fifteen seconds; later from thirty to sixty seconds, rarely longer. The longest douches occupy two minutes. The pressure of the water is ten to fifteen pounds, or at most twenty to twenty-five.

For the administration of the *shower-douche* the water is conducted to a disk about eight feet above the floor, having numerous perforations, each one-eighteenth to one-eighth inch in diameter. When the holes are one-sixteenth inch in size the water falls as spray; when one-eighth inch, in the form of heavy rain.

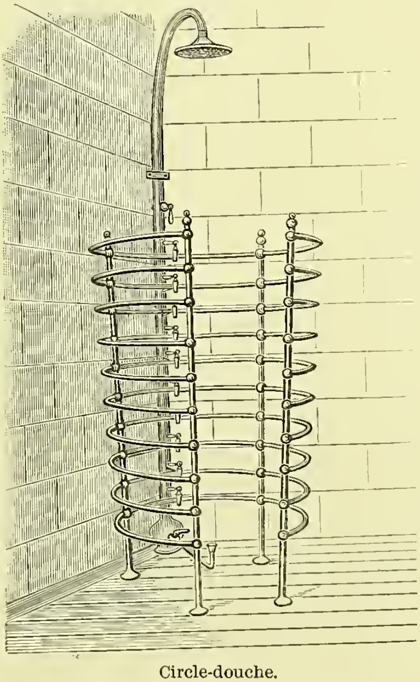
The *column-douche* is a large jet of water issuing at a certain angle from a large brass tube, having a diameter of one-fourth to three-

fourths of an inch. The douche thus produced constitutes the most energetic mode of percussion. It is applicable only to parts not very sensitive, as the large muscular masses of the limbs, and is, in the beginning, continued for not more than four or five seconds. Formerly this douche was much employed, but at the present day it has been almost completely abandoned.

FIG. 10.

FIG. 11.

FIG. 12.



Circle-douche.

The *dauphin* is a diminutive column-douche.

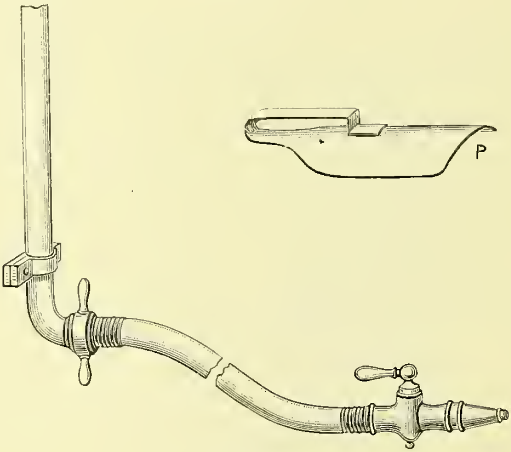
The *douche of concentric layers* is also but rarely employed. It consists of an end-piece having two concentric slits (Fig. 10) one-

twentieth of an inch in diameter. It is less stimulating than the rain-douche. The *bell* (Fig. 11) is a variety of this form of douche. It has a single aperture, and represents a less powerful means of percussion than the column-douche.

For the *circle-douche* (Fig. 12), termed also the *dust-douche*, a special apparatus is necessary. It consists of incomplete independent rings, separated from each other by a distance of four to six inches, and rising to a height of a yard. The rings are pierced on their internal aspect by two rows of very small holes and furnish small concentric jets, which produce a fine circular douche, while a central douche above the head of the patient allows a gentle rain to fall.

The duration of this douche should be short; its action is distinctly revulsive.

Fig. 13.



Lance-douche.

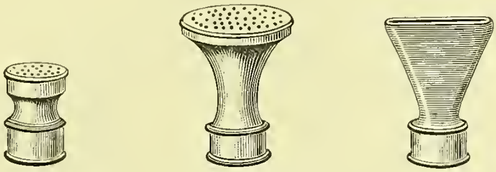
The *mobile-jet douche* or *lance-douche* adds to the action of the cold a mechanical effect, the strength of which can be easily varied by modifying the force of the jet and the pressure of the water. (Fig. 13.)

The ordinary lance-douche has a diameter of one-half to one inch. The jet which it furnishes may be broken by means of a stop-cock. The terminal piece may be replaced by a small tip (needle-douche) or by a special end-piece having the form of a fan. (Fig. 14.)

The jet should always be alternated when directed against the chest or the abdomen; at the end of the sitting it is thrown unbroken against the feet, in order to produce strong percussion upon them.

Of these diverse forms of douches, we may say that their effects vary with the manner in which they are given. When the duration is very brief the water may be very cold; in general, temperature and duration should vary inversely. The cold douche is a powerful sthenic agent, yet by regulating the important functions it may exercise a sedative influence.

FIG. 14.



Some writers believe that patients should be prepared for the cold douche by a preliminary use of water slightly warmed; but the cold douche of a second's duration can be supported, as Bottey remarks, by the most feeble and the most excited patients.

Burgonzio precedes the douche by a sponging of the face, the præcordial region, and the spinal column; but the procedure is of doubtful value. More valuable is his suggestion to use the column-douche with a wide angle, and a minimum duration of sixty seconds, when a stimulating action and an increase in muscular force are desired.

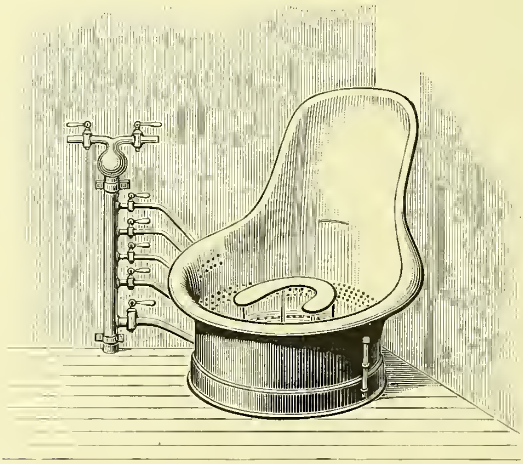
Local douches are seldom employed as isolated procedures. They are commonly resorted to during the course of or after the general douche when a special local effect is wanted. These douches present many varieties, among which may be named the hepatic douche, the splenic, the vertebral, the epigastric, hypogastric, the sitz-bath in running water, the foot-douche, and the foot-bath in running water.

Priessnitz employed the local column-douche for applications to the abdomen, but the broken jet, or even the sprinkling-douche, should be preferred to such severe measures. In some institutions a vertebral douche is given by the aid of a vertical tube closed at its upper extremity, and pierced laterally by from one to three rows of holes, opposite to which the patient places his back.

The sitz-bath in running water serves a number of uses and merits a brief description. The apparatus consists of a vessel with a double bottom, having the form of those employed in giving the ordinary sitz-bath. It is provided with several rows of fine holes, the axes of

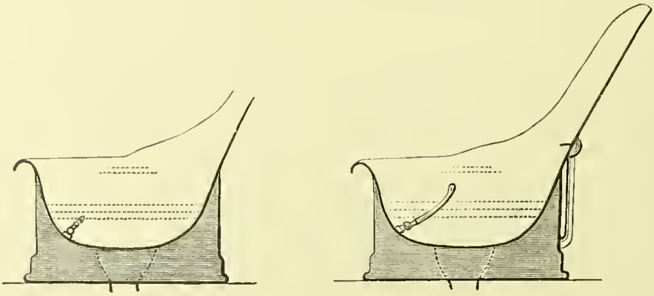
which are disposed in such a manner that the issuing jets converge toward the centre of the basin. The liquid runs out through a waste-pipe at the bottom. The patient, seated upon a metallic rest, receives a spray-bath on the loins and about the pelvis. There is also pro-

FIG. 15.



vided a vertical spout pierced by fine holes, for the purpose of giving a hemorrhoidal or anal douche. Sometimes the back of the apparatus possesses a transverse slit or a triple row of small holes, permitting the administration of a lumbar douche. (Fig. 15.)

FIG. 16.



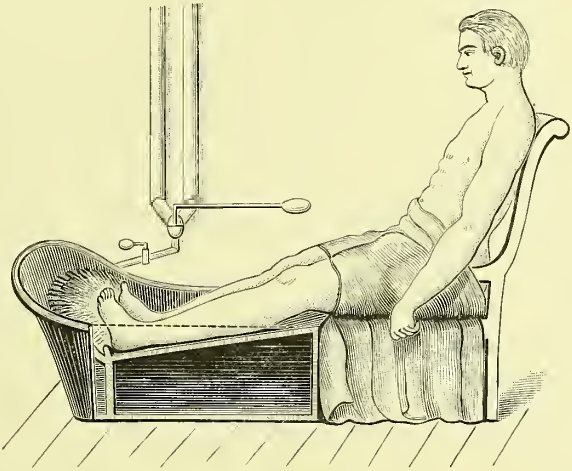
At the junction of the third and lowest fourths of the sitz-bath a nozzle is placed which directs a stream against the perineum, constituting the perineal douche. (Fig. 16.) The same apparatus also

serves for giving vaginal douches by means of a movable conduit, a speculum having previously been introduced into the vagina.

The foot-douche and leg-douche is administered by means of a special contrivance which consists of a tub of wood or metal, the bottom forming an inclined plane, upon which the limbs rest. (Fig. 17.)

From a number of holes piercing the walls opposite the soles of the feet small jets are forcibly projected against the lower limbs. An

FIG. 17.



Foot-douche.

energetic reflex effect is thereby obtained in the calves and the thighs and as far as the pelvic organs, but it should be remembered that this form of douche produces a painful sensation. Caulet, who has made use of this douche with water at from 52° to 60°, has observed that the foot-douche thus administered during a period of from one to three minutes produces at first only sensitiveness, then more or less pain, and, finally, excruciating suffering. At the end of the application he has noted a chill and extreme smallness of the pulse. A powerful derivative action is thought to be obtained by this procedure on the pelvic organs.

Under the name of cephalic douche, Burgonzio describes a stream of cold water which is forcibly projected against the forehead and temples. In the beginning the application lasts two to four minutes, and later from eight to ten. During the first two minutes the patient

experiences an insupportably painful sensation, but during the following moments there is a sense of veritable *bien-être*. This method is sometimes successful in rebellious headaches.

Affusions. The cold applications without percussion are of two kinds—general and local.

Affusions are practised with water at from 70° to 80°, and when the patients are accustomed to it with water at from 40° to 50°. The procedures, which are too simple to require description, have a duration of forty to sixty seconds. During their continuance the patient is urged to make movements, and at the close is subjected to dry friction. The mode of administration may be varied according to the end desired. A form of treatment, which is practically an affusion, is the wet sheet. A heavy linen sheet of ample size is soaked in water at 50° to 60°, and then expressed by wringing. The patient having moistened his face and chest, the sheet is folded over his shoulders, and the entire body, from the neck down, including the lower limbs, is enveloped in it. The patient rubs himself with the cloth anteriorly, while the attendant, in the same manner, practises friction on the posterior aspect of the body. The naked feet rest on the floor, and are not surrounded by the sheet. Friction is continued for five minutes until heating is produced. The wet sheet is then removed and replaced by a rough, dry cloth, with which light friction is made. This procedure may be followed by massage and rest in bed. It is better, however, if the patient dresses and takes a short promenade. By another method the sheet is wet in water at 66° to 76°, and then without wringing is thrown over the shoulders and so disposed that the entire body is enveloped in it. It is left in place until slightly warm, while the limbs and trunk are lightly rubbed with the flat hand. When the sheet is warm it may be replaced by another; the wrapping may be repeated several times, or, the sheet remaining, two or three bucketfuls of water are dashed upon the body.

Bottey, who recommended this measure, considers it as tonic and sedative, as well as mildly antipyretic.

The best antithermic means of "wrapping," and the only one applicable to adynamic patients, is the wet sheet just described, the sheet being renewed every five or ten minutes, according to the rapidity with which it becomes heated, until a decided chilling is produced. Five sheets will ordinarily be required. Four successive wrappings have the same effect as a bath at 75°, lasting ten to fifteen minutes.

When there is a tendency to headache, a cold compress is applied

to the head during the pack, and a hot foot-bath is given afterward.

The effects of the wet sheet are identical with those of the douche, merely less intense. The method may be utilized in the beginning of treatment in the case of delicate individuals; it may also be considered as a good procedure for domestic hydrotherapy.

The moist pack was the principal procedure of Priessnitz. Its effects are variable, depending upon the mode of use, but as a hydrotherapeutic measure it has a tonic and sedative action. A wet sheet is spread upon a woollen blanket which has previously been laid upon a small iron bed.

The patient is then placed upon the sheet and successively wrapped in the sheet and the blanket quite firmly, but without impeding the respiratory movements. The wrapping lasts only ten to twenty minutes; it should be discontinued the moment reaction begins—that is, when the pulse tends to become more rapid. During the applications a cold compress is placed upon the head and the window is kept open.

In some cases the application is followed by washing with cool water at 70° to 80°, and by friction. This procedure may be employed to prepare the patient for the use of the large douche.

Von Ziemssen and Immermann have devised a useful formula which expresses approximately the relative value of the various procedures employed to reduce temperature. Designating cold affusions by A, the cold wrappings by E, the graduated bath by P, the cold bath by F, we have: A : E : P F = 1 : 2 : 3 : 4.

To complete the consideration of the divers means of reducing fever, it is necessary to describe a procedure recently suggested by Fenwick, of London. It depends upon the production of cold by the evaporation of water from the surface of the body.

Upon a small iron bedstead is spread a sheet of mackintosh, then a woollen blanket, doubled twice, and upon this the patient is placed. Water is then poured upon him by means of a sprinkling-can for a variable period, usually about ten minutes. At first water at 55° was employed, but it is better to use warm water at 100°. The method is efficacious, particularly when resorted to just at the time when the temperature is falling spontaneously. But it appears to us that its inconveniences exceed its advantages.

Affusions, in spite of their feeble power, are, nevertheless, generally painful, and are less easily supported than the cold bath. Liber-

ally given they may produce quite a notable fall of temperature. They should be administered forty minutes at a time as a maximum. Frequently friction of the limbs and trunk is added with advantage.

In the hands of its original promoters this method proved very efficacious in the treatment of certain malignant eruptive fevers for the purpose of bringing to the surface the fading or slowly appearing eruption, and in grave (cerebral) forms of rheumatism as a means of determining the inflammation to the joints. We have employed it with advantage in various forms of delirium, and have been accustomed in these cases to pour three or four pailfuls of water (at 65°), holding 10 litres each, upon the patient's head, which was protected by a cap or folded compress. The patient at the same time was given a half-bath.

In establishments for hydrotherapy the affusions are administered in a bath-tub half-filled with tepid water. A cold compress is placed on the head and the shoulders are sprinkled by means of a watering-can with cold water. When the water is from 60° to 65° and the duration of the application brief, an excitant effect is secured. When the water is warmer and the duration prolonged, the effect is sedative.

Baths. The tub-bath occupies a special place in hydrotherapy, for it is almost exclusively employed as a means of reducing temperature. The cooling baths comprise the cold bath, the graduated cold bath, and the half-bath.

The ordinary temperature of the cold bath is 76° ; sometimes the water is colder, having a minimum temperature of 68° ; sometimes a higher temperature is chosen. The bath at 75° is the typical cold bath, that which is employed in the treatment of typhoid fever after the method of Brand. The duration of immersion is ten to twenty minutes—until the second chill appears.

In the administration of this bath it is important to take the precautions given on a previous page. The patient should be watched by the physician or by a competent attendant, whose duty it is to regulate the details of the immersion and its duration, and to supervise the treatment to be pursued after the patient's exit from the bath.

Usually the patient is wiped dry with a cloth and then wrapped in a large woollen blanket, which is twisted below the feet; he is then permitted to lie quietly on the bed until the peripheral heat returns.

[The most important thing for the attendant to do while the patient is in the bath is to keep up constant friction on the surface of the body,

and so, by rubbing, to equalize the distribution of blood in the internal and external bloodvessels.—Ed.]

The graduated cold bath has an initial temperature of 95° to 100°. By the addition of cold water the temperature is progressively lowered to 75°. The duration of such a bath is twenty to thirty minutes, and its effect is equivalent to that of a cold bath at 75°, lasting ten minutes.

The half-bath is designed to facilitate the friction, by which the loss of heat is increased and reaction elicited. The bath-tub is filled to a depth of 6 or 7 inches, so that the patient is immersed only to near the umbilicus. It is then very easy to practise friction of the limbs and trunk and to make cold affusions to the head.

This form of bath is not solely employed as a measure for reducing temperature. It may be used in hydrotherapy, being then generally followed by a shower-douche given with water at 60°.

Cold affusions may be made in a bath-tub, either without previous filling of the tub with water, or in the course of a half-bath. They represent one of the earliest methods of lowering temperature, and have been praised by Currie and by Trousseau, Bartels, Jurgensen, and Liebermeister.

The pool-bath which is used in hydrotherapy is a large tank, access to which is obtained by means of a few steps which descend below the surface of the water. The water is at a temperature of from 70° to 80°. The patient remains in it for a period varying from a few seconds to a minute. The effect obtained naturally varies with the temperature and the duration of the sojourn. A short immersion is followed by a sense of comfort, a sedative effect, and a tendency to sleep, while a more prolonged stay tends to produce fatigue.

In continuing the description of the procedures in which cold is applied without percussion, we come now to the partial applications.

The bath of the legs is given with water at a moderate temperature of from 75° to 85°; and this application, when sufficiently prolonged, exercises a powerful revulsive action.

The sitz-bath in still water usually has a temperature of 75° to 85°. During its duration, which is at the most fifteen minutes, a cold compress is placed on the head and forehead to prevent the occurrence of cephalalgia. (Fig. 18.)

Of the strictly localized applications the partial wet wrappings already named may be considered, by reason of their long duration, as antipyretic as well as hydrotherapeutic measures.

Having considered the employment of cold water in hydrotherapeutic procedures, we may now consider the use of hot water, particularly when percussion is a factor. If the general douche has a temperature of 92° to 96°, at which we begin to call it warm, the evaporation which takes place during its application and immediately afterward causes a slight cooling of the body.

FIG. 18.

Sitz-bath.

As the impression of heat given by the douche is less strong than that produced by complete immersion, the temperature must be 96° or higher before it is felt as hot. Temperatures of 104° to 114° are readily supported; the latter figure is, however, rarely surpassed. It is customary to begin with water at 86° or 90°, and to raise the temperature to 104° or to 108°. A proper apparatus for graduating the temperature and also for ascertaining the degree of temperature at any particular moment of the application is an essential requisite.

The hot douche is generally administered with the interrupted jet; while when the shower-douche is used the water is only slightly warmed.

The procedures in which percussion forms no part are numerous; many are in the form of wrappings, and are intended to cause sweating.

Sweating may be produced both by means which check the loss of heat and those which absorb the heat. To the first belong the hot dry- and the hot wet-pack.

The hot dry-pack is applied in the following manner:

Upon the mattress one or two blankets are placed, and upon

them a large sheet. The patient is laid on this, with the arms extended along the body, the head resting upon a low pillow. The sheet is then lifted and wrapped around the body; at the feet it is twisted into a rope and laid under the heels. The blankets are then brought up and folded over the sheet. A hot-water can is placed at the feet, and, if necessary, a feather-bed or blankets are put on. The patient remains quietly in the pack for from one to three or four hours. If too long continued, malaise, headache, tinnitus, flushing of the face, vertigo, and, finally, nausea, thirst, and fatigue may develop.

In regard to the effect upon the temperature produced by this pack, that of the skin rises about 4°; in the cavities the increase is from 1° to 2°, or more. The amount of water lost during prolonged application is approximately 100 grammes.

The hot wet-pack is identical with the dry pack already described, except that the sheet is wet and the application is prolonged until sweating occurs—namely, from one and a half to two and a half hours. The patient is afterward subjected to a cold bath or is rubbed with a wet cloth. The wet-pack produces in the beginning a disagreeable sensation and slight chilliness; but when the temperature commences to rise the patient experiences a sense of comfort and becomes drowsy. During the application the cutaneous vessels are contracted, but dilate subsequently. The temperature of the body is slightly raised by the pack. Priessnitz has employed the pack as a preparatory measure for the douche. The effect is a brief, primary stimulation, followed by a sedative action. According to Vinaj, it is never debilitating. The partial wrappings are more frequently employed than the wet-pack.

The half-pack, or moist-jacket, is a moist application limited to the trunk. A large wet compress is placed on the anterior surface of the trunk and covered with some impermeable cloth, the whole being maintained in position by means of a flannel bandage.

Applied at bedtime, the half-pack, has a somnifacient influence. In the morning the patient is washed or friction with cold water is practised. The general effect of the half-pack is sedative.

The abdominal compress is often used in dyspeptic states.

In addition to those named, other localized moist wrappings are occasionally employed, as the thoracic belt, the cervical compress (Oppolzer), articular wrappings, and compresses to the feet to combat coldness of the extremities.

The bath is the procedure most frequently employed. The ordinary tepid or temperate baths have a temperature of 92° to 94°; sometimes they are termed *indifferent*, because, theoretically, they should produce no physiological effect. In febrile cases, however, a bath of an hour's duration exercises a sedative action, generally ascribed to the imbibition of water by the skin and the protection of the nerve-endings against external stimuli. In febrile patients it moderates the temperature—a fact known to Hippocrates; while, according to Liebermeister, it does not do so in healthy man. Liebig has noted only insignificant fluctuations. Nevertheless, according to Théry, there is a slight diminution of temperature after the bath at 92° to 98°, continued for at least a half-hour; and C. Chauvet has made the same observation on the bath in running water at 94° to 96°. The fall of the central temperature takes place gradually, continues for some time after the bath, and then it slowly disappears.

Recent investigations (Zawadzki) have shown that the temperate bath stimulates general nutrition.

The hot bath, having a temperature of 105° and upward, is followed by a rise of the body-heat of from 2° to 6° (Liebermeister), and by more or less abundant sweating, which persists for a variable period of time after the termination of the bath.

The chamber in which the vapor-bath is given may be small, for private use, or large enough to accommodate several persons. In the former instance the room is usually six feet square, and has a height of eight to nine feet. The ceiling is arched or horizontal.

Vapor-bath. The chamber should be provided with a wooden bench, a steam-spigot on the side opposite the bench, and a bell and a thermometer placed near the patient. A basin of cold water and a douche apparatus complete the furnishing of the room.

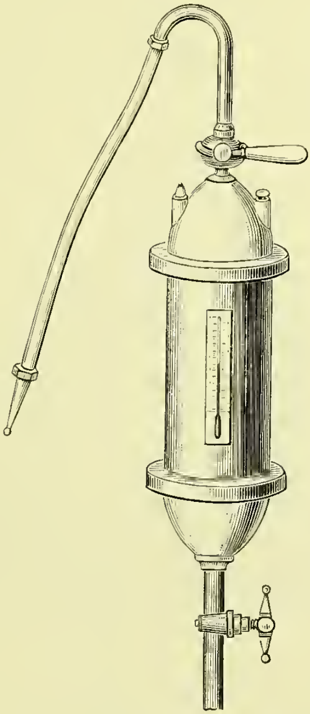
The appointments of the moist chamber for general use vary greatly in different establishments. A series of steps is generally constructed upon which the patient can either sit or recline. According as the patients occupy the higher or lower steps, they will be environed by an atmosphere having a higher or lower temperature.

The temperature commonly varies from 96° to 170°, with a mean of 114°. The patient, during his sojourn in the vapor-bath, generally divests himself of all clothing; it is only in establishments where the steam chamber has a temperature of 90° to 96° that a light garment is worn.

At the commencement the heat of a vapor-bath at 114° is oppressive, but very soon the discomfort disappears, respiration becomes free, and sweating begins. Later, however, fatigue develops, and the bath is generally discontinued at the end of thirty to forty minutes. Frequently other hydrotherapeutic measures are combined with the vapor-bath.

Wigand has estimated the loss in weight produced by the bath to be about 15 grammes per minute, but it must be remembered that

Fig. 19.



Vapor-douche.

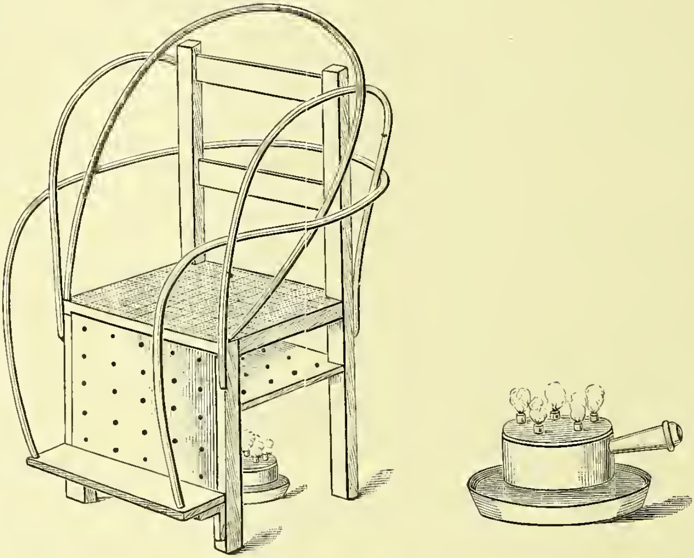
as the atmosphere of the chamber becomes saturated the loss sustained by the body diminishes proportionately. When the temperature is from 110° to 122°, and the length of sojourn ten minutes, the loss of water, according to Oertel, is from 222 to 743 grammes. A definite ratio, either to body-surface or body-weight, does not seem to exist.

The elevation of the central temperature is at first gradual, but

becomes rapid in a short time. When the atmosphere in the chamber has a temperature of 92° to 94° the rise amounts to a few tenths of a degree only (Liebermeister); when it is 122° to 128° an increase of from 98° to 104° has been observed after a ten minutes' sojourn in the chamber (Bortels and Jürgensen). Frey and Heiligenthal found in the case of a vapor-bath having a temperature of 122° to 138° a rise of the central temperature to 102°, after a period of thirty minutes.

The vapor-douche is a jet of steam directed from a reservoir, usually during the course of a vapor-bath, against some portion of the body. (Fig. 19.) Solutions of aromatic herbs may be introduced into the reservoir for medicinal purposes.

FIG. 20.



Chair for Hot-air Bath.

The hot-air or the vapor-bath may also be administered by other methods than that just described, viz., by means of a lamp or a hot-box.

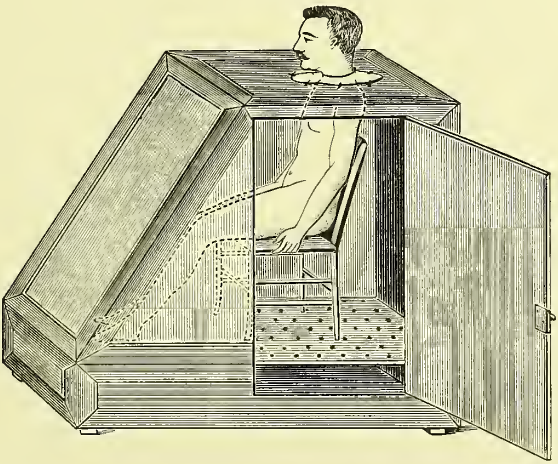
The hot-air bath, in which the air is heated by means of a lamp, originated in the seventeenth century. The chair upon which the patient sits has a perforated seat, and is provided with hoops rising to the level of the shoulders, and with a small board to serve as a foot-rest. The patient, entirely disrobed, is enveloped up to the neck with a woollen blanket, which in turn is covered with an impervious

cloth. An alcohol lamp with several burning wicks is placed under the chair; it heats the air, generally to a temperature of from 104° to 122°. In order to favor sweating the patient is urged every ten minutes to drink a glass of cool water. (Fig. 20.)

[The lamp ought never to be put under the chair, as the blanket may take fire and the patient be seriously burned. It should be put under an inverted funnel, which is then placed with its small end under the blanket, the lamp being to one side.—Ed.]

As long as the temperature does not rise above 122° the pulse and the internal temperature are not materially affected. But when a higher degree of heat is attained—132° to 140°—the patient experiences a burning sensation in the skin, becomes thirsty, nauseated, and has tinnitus aurium, while the pulse-rate grows more frequent and the internal temperature rises.

Fig. 21.



The advantage of this procedure consists in that, slightly modified, it may be employed when the patient is bedfast. For this purpose hoops are placed beneath the blankets in such a way as to create an air-space into which a pipe is conducted. A burning lamp is placed under the other end of the pipe and the heated air rises into the air-space between the patient and the blankets.

Occasionally a box is used instead of the chair. This box may be made of wood or of marble; the lid is pierced by a hole for the passage of the heat. The patient sits upon a stool and protrudes the

head through the aperture in the lid so as to respire freely. A small collar closes the space between the neck and the borders of the orifice. (Fig. 21.) The box may be employed for the administration of vapor-baths, simple or medicated, or of the hot-air bath alone. For the latter purpose the air is heated by means of an alcohol lamp, hot iron slabs, or heated bricks.

Dry-air Bath. In the dry air-chamber, the atmosphere not being saturated with watery vapor, sweating is more easily secured, and is more abundant than in the vapor-chamber; but it ceases immediately upon leaving the heated room (Bonnal).

The effects produced by the dry air-chamber are more gradual in their onset than is the case in the moist air-chamber; hence, on the whole, the former is more agreeable than the latter.

The capacity for heat of air being less than that of water, and sweating and evaporation being greatly favored by dryness, it is readily comprehended how experimenters have been able to remain in hot air-chambers the temperature of which surpassed that of boiling water. In the studies of Fordyce and Blagden and of Dobson, the temperature rose to 294°, and Bonnal recently has pushed it to 308°.

Under ordinary conditions the temperature of the blood rises less in dry than in moist air. In a chamber having a temperature of from 122° to 194° E. Large observed an elevation of 2° at the end of an hour to an hour and a half. Henning has noticed a rise of 4° after a fifty minutes' sojourn in a (hot-air) chamber having a temperature of 170°. The return of the temperature to normal is gradual.

Hot and Cold Douche. The different procedures which have been described may be combined in diverse ways, according to the needs of practice. Most commonly hot and cold applications are made alternately, or a prolonged hot application is followed by a single equally long-continued cold application.

When water of sufficient warmth is employed, and the duration of the application is somewhat prolonged, a distinct redness of the skin is produced. If at that moment cold water is suddenly applied, the redness disappears, then becomes more marked, and the sensation of cold is made less intense. This reaction sets in promptly, as a rule; in some cases, however, it is retarded. The cutaneous effect varies in proportion to the difference between the temperatures of the means employed in proportion to their respective duration and to the force of percussion.

By combining several factors more varied effects can be produced than by any simple procedure.

One of the principal of this type of procedures is the Scottish douche. Two pipes, one of hot and one of cold water, are conducted into a common reservoir, whence issues the discharge-pipe. By aid of a proper apparatus the temperature of the water may be readily varied by a simple manœuvre of the faucets. As the mingling of the two streams, by reason of the pressure, is almost instantaneous a single tube need only to be provided, but it is better to have two, both of which are attached to a mixing reservoir.

The douche is nearly always administered with the movable jet, and at a progressively changing temperature. Bottey, who has thoroughly studied the subject, distinguishes these varieties: the revulsive douche, the revulsive tonic, and the sedative and tonic douche.

The *revulsive douche* is given with hot water, from 114° to 120°, for a period of three to five minutes, or until a cherry-red coloration of the skin is obtained. The surface is then sprinkled with cold water, which causes the appearance of a scarlet redness. An application of water at 50° for from five to six seconds suffices for this and serves to carry off the excess of heat. The color of the skin is the proper guide in its use.

The procedure does not produce a fall of temperature, but exercises a strong analgesic influence.

To obtain the *revulsive and tonic* effect the method of administration is the same, except that the application of the cold water is prolonged after the appearance of the scarlet hue, until the patient has a sensation of cold. After the douche the feeling of warmth returns very rapidly.

When patients cannot endure hot water at 114°, or when the red color does not appear in spite of the use of water at such a temperature, the revulsive and tonic effect may be obtained by means of a double Scottish douche.

The loss of vascular tone produced by the first cold douche renders the second Scottish douche more efficient. The duration of the two Scottish douches should not exceed that of a single one.

The *sedative and tonic douche* is Bottey's modification of that which Tartivel has described as the sedative form of the Scottish douche.

The douche is begun with water at 96°, the temperature being

raised progressively during a space of thirty to sixty seconds, until a temperature of 104° to 108° is reached. This maximum temperature is maintained for one to one and one-half minutes; it is then allowed to fall until, at the end of thirty seconds or a minute, the water is cold.

After the application the skin remains red; the temperature is a trifle lower, but returns to normal within two hours. This form of douche may be employed to prepare feeble and tired patients for the use of the cold douche.

The alternating douche is not so frequently employed as the Scottish douche, nor has its action been so thoroughly investigated. It consists in the alternate application, several times in succession, of hot and cold douches, all of equal duration. The effect is more stimulating than sedative. The total duration is generally two to four minutes.

In the alternating bath the patient is placed in a bath the temperature of which is 94° to 98°. He remains in this for a period of five to fifteen minutes. The water is then rapidly cooled, and as soon as the patient has become chilly, generally when the temperature has reached 74° to 78°, he is removed and rubbed with a coarse towel. In the meantime the cold water is replaced by hot, and then the patient is again plunged into the tub. At the end of two or three minutes friction is again practised. The effect is tonic and sedative.

Partial applications may also be combined in various ways. A good example is the procedure employed by Winternitz in certain forms of dyspepsia, especially in those attended by cardialgia and vomiting. The body and thighs are wrapped in a cold, wet sheet, while a coil is applied to the epigastric region, through which water at 104° is allowed to flow. After a preliminary sensation of cold the patient experiences an agreeable feeling of warmth.

The *Russian bath* is a vapor-bath followed by a cold application. The patient first enters the vapor-bath. At the termination of this he lies down upon a couch and is thoroughly rubbed. He is then given a shower-douche, after which he plunges into a tank, which can be filled with hot or cold water. In the last chamber he again reclines upon a bed, while friction is administered for the second time. The effect is tonic and sedative.

The most complex bath is the *Roman*, *Turkish*, or *Moorish* bath, as it is variously called. The establishments where these baths are given are scattered throughout the Orient, especially among the fol-

lowers of Islam (Moorish baths), and it is truly remarkable how great a skill in massage prevails among these nations. Introduced into Europe about twenty-five years ago, these baths (under the name of Turkish bath) are now in use in England, France, and Germany, and are also very popular in the United States.

The practice of massage dates back to the times of the ancient Greeks, from whom, as also from the peoples of Asia Minor, the Romans borrowed it. Among the Moors it is performed by the Mozabites, an industrious and highly civilized tribe. For the massage of females negresses are employed, who are, however, much less skilful. Amedee Maurin has clearly described the construction of the Moorish establishments and the manner in which the baths are given. The buildings are divided into two essential parts; the central part or chamber represents the sudatorium, vaporarium, or laconicum of the ancients. The lateral parts, the galleries or corridors, have public or private rooms, in which the bathers rest. Beneath the chamber is the oven (hypocausis of the ancients), in which a constant fire is maintained with wood. The water in the chamber modifies and moistens the atmosphere.

The fire of the oven heats the water in the reservoir, which is placed in the centre of the chamber and is surmounted by a marble table. The room has the form of a Latin cross, so that the temperature is not evenly distributed. Above the table the thermometer registers 144°; at the extremities of the arms of the cross it is only 114°. On the floor and along the wall are vases of marble or onxy, indicating the hot and cold spigots.

The bather first rests on the marble table until copious sweating is produced; then he delivers himself up to the masseur, who kneads the anterior and posterior parts of the body and then applies enough friction with a camel's-hair glove. This is followed by ablutions with soap and warm water; the body is then sprinkled with perfume; then comes the toilet; a short rest and a cup of tea complete the process.

[In England and America the method of giving the Turkish bath consists in having the patient pass from the ordinary living temperature into a hot room, and after remaining here a variable period until sweating is established, to pass into successively hotter rooms, where a still more profuse sweat is produced; from here he passes into the hands of the rubbers, who soap and rub him, and, finally, give him a cold douche or he takes a plunge in a pool, and is met

by an attendant, who dries him and allows him to rest and sleep for many minutes. This bath establishes a good vasomotor tone, relieves the kidneys, and is valuable for rheumatism and gout and in some cases of obesity. It is contraindicated in cases of cardiac dilatation—Ed.]

The Turkish bath as applied in Europe has a temperature of 122° to 212°. Massage is also administered and affusions of cold water made; in some cases the cold tub-bath or the douche is given. It is a difficult matter to employ these procedures in a methodical and scientific manner in a private house, and hence they are scarcely applicable to those who are acutely ill. In the tropical countries the use of these baths is universal and constitutes an important sanitary measure. Diaphoresis is profuse, especially when liquids are taken during the bath. The effect of the multitude of procedures is not, as we might expect, a sense of fatigue, but rather a feeling of ease and comfort. Large states that these baths produce a stimulation of all the nutritive processes.

According to Oertel's studies, made at the Turkish baths of Kolditz, the quantity of water lost from the body varies from 500 to 1000 grammes.

Clinical Application.

We have now completed the description of the various hydrotherapeutic measures and can begin the discussion of the principles governing their practical application for purposes of treatment.

When we have to deal with a grave case it is best to carry out the treatment in a properly appointed establishment under the supervision of an experienced physician, but the majority of patients may continue to live at home or at a hotel.

In any case, the hydrotherapeutic regimen should not be instituted without due deliberation, since, if not methodically carried out, it may be fruitful of harm.

When the indication is pressing any time in the year is suitable for commencing the treatment, but under ordinary circumstances a moderately cold and dry season is preferable. In the case of feeble patients incapacitated for taking exercise, and particularly those suffering from diseases of the air-passages, the summer is the best season for inaugurating the treatment, while for constitutional diseases (diabetes, obesity, neuroses, etc.) the winter season is most favorable.

The duration of the treatment is usually prolonged. Not rarely the morbid phenomena are somewhat aggravated at the end of the

first few days, but this does not constitute an indication for suspending the treatment. An intermission of several days is advisable, however, if a marked degree of excitement is produced.

In those cases where the treatment has to be long continued it is wise to suspend it from time to time. It will often be observed that the patient's condition ameliorates more during the periods of rest than it did during the continuance of the treatment.

The therapeutie effects of hydrotherapy are various; they may be described under the three terms of stimulative, sedative, and revulsive.

Stimulation, that is, the production of a strong reaction, is obtained by means of cold applications having a short duration and combined with very active mechanical procedures.

The most stimulating methods are simple washing with friction, the Scottish and the alternating douche, and, most efficient of all, the cold douche, given with the movable-jet or the shower-douche.

The sedative influence of hydrotherapeutic measures is secured by lessening the intensity and prolonging the duration of the reaction. The means employed may be quite powerful. Not infrequently it is necessary to prepare the patient by gentler measures before subjecting him to the more energetic procedures. Thus, we may precede the use of the cold bath, the most powerful means of sedation, by tepid affusions or tepid baths or the wet sheet.

Other sedative methods are the alternate use of hot and cold, as the vapor-bath with active applications of cold water, and the sedative Scottish douche previously described.

Lastly, a sedative action can also be obtained by attenuating the sensitiveness of the terminal nerve-filaments by a long sojourn in the tepid bath, to which mucilaginous substances may be added.

Revulsion, that is, the determination of the blood to the surface for a prolonged period, is produced by means of hot applications or by alternate applications of heat and cold. The revulsive Scotch douche, already described, is one of the best agents for this purpose. When the patient is confined to bed the dry or wet pack, followed by cold affusions, may be employed.

The conditions in which hydrotherapeutic measures are advantageously employed are manifold. In the treatment of fever frequent use is made of cold; and in sthenic cases cold applications of short duration are very valuable. Prolonged local applications of cold exercise a marked antiphlogistic effect.

[The most important of these is the so-called Brand method of

treating enteric fever, which consists in the immersion of the patient in a bath of the temperature of about 70° F. as frequently as the fever reaches 102.5° F. The patient should be gently lifted into the tub, and be rubbed thoroughly while in the water to bring the hot blood to the surface. Immediately on his entrance his head should be cooled by a cold douche or by means of an ice-bag. Sometimes a little whiskey or brandy is given before he enters the bath; but, as a rule, the stimulant is best reserved for the time of exit from the tub. The temperature should not be reduced below 100°, as it may continue to fall and the patient go into collapse. After the bath has accomplished its purpose the patient is lifted back on to the bed, is wrapped in a sheet and then in a light blanket, without being dried or rubbed. If the chill is marked, a hot-water bag may be placed at the feet and a half-ounce or thereabouts of whiskey given to him. Often a peaceful sleep follows the bath. In the hands of Brand, the mortality of typhoid fever under this method has only been about 1 per cent. In the hands of others it has been higher, but in nearly every case less than with other plans of treatment.—Ed.]

In diseases of the nervous system recourse is had to diverse forms of hydrotherapeutic treatment, according to the end desired; for the alleviation of pain revulsive procedures are especially indicated. In rheumatism hot or mixed applications, often combined with massage, are of undoubted value. The styptic action of cold or the reflex effects engendered by energetic local applications of heat or cold are an important means of controlling hemorrhage. Finally, in the so-called diseases of nutrition, good results are unquestionably obtained by the use of hydrotherapeutic agents.

There are a number of contraindications to the employment of hydrotherapy. As a general rule, the organic diseases, such as pulmonary tuberculosis, general paralysis, diabetes mellitus, Bright's disease, chronic diseases of the heart and the vessels, preclude the use of cold applications. It is true that in the incipient stages of these maladies such applications, particularly of the gentler variety, may be employed; but as soon as there is a state of general debility or of weakness of the circulatory organs the contraindication becomes absolute.

The existence of disease of the skin contraindicates the use of certain special procedures, among them the use of cold water and the sweating by means of the lamp. Baths, simple or medicated, the vapor-bath and the tepid-bath, or the hot douche, are, on the other hand, very useful in certain forms of skin diseases.

PART V.

MINERAL WATERS.[1]

THE custom of spending the summer at a resort possessing a mineral spring is becoming more popular year by year, especially among the dwellers in large cities. This is due in all probability more to a desire to be fashionable than to a real necessity. We do not wish to imply, however, that mineral springs are of doubtful value; indeed, many of them are powerful agents, but it seems to us that their popularity is not entirely due to their therapeutic usefulness. It is the sufferers from chronic disease and the semi-invalids which find in such resorts a proper and necessary rest from the pressing cares of modern city life. If the place is rightly selected, such persons will be greatly benefited by the treatment; but a mineral spring is a two-edged sword, and it may do harm if not suited to the patient's state of health. Hence it is exceedingly important to have a knowledge of the properties and actions of mineral waters.

The use of mineral waters dates back to ancient times; it was quite prevalent among the Romans, who founded many establishments in Gaul. Nevertheless our knowledge of their medicinal properties is almost entirely modern; yet it is far from complete, and mineral waters still rank among the quasi-mysterious agents.

The action which they produce depends in general upon four factors: (1) Upon their mineralization, or, rather, upon their chemical and physical properties; (2) upon their temperature; (3) upon their mode of employment; and (4) upon the hygienic and adjuvant conditions (especially the climate) of the resort.

We shall briefly study these factors in detail.

Durand-Fardel defines mineral waters as those natural waters employed in medicine by reason of their chemical composition or their temperature. This definition would include ordinary water raised to a certain temperature. Many authors do not agree to

[1] The parts on Thermic Agents and Hydrotherapeutic Measures should be read with this part.

this, but affirm that mineral waters, no matter what their constitution, exert an action which differs from that of the ordinary potable water.

The point of emergence of mineral springs is extremely variable; it may be in ancient or in recent strata, in crystalline or in sedimentary rocks. Springs are scattered over the entire surface of the globe—in all zones, in all countries.

Those that have a high temperature are generally in the neighborhood of volcanoes; when found in transitional strata they always issue from granite rocks.

Mineralization. The mineralization or chemical composition of the spring is usually in accord with the nature of the subterranean strata traversed by the water. Such surface-waters as are counted among mineral springs obtain their properties by *lixiviation.*

The character of the bed of a spring does not always give a clue to its composition, for the same regions may possess waters differing considerably. The bases are derived from the containing strata, but the dissolved acids may have their origin at a remote distance.

Certain waters—several of great importance—are mineralized to a less extent than drinking-water; their specific gravity is scarcely above that of distilled water.

The chemical composition of mineral waters is remarkably constant, although the true composition must still be considered almost unknown. It is customary to make two kinds of analysis. In the one the component elements, or the simple compounds, such as acids and bases, are determined; this is known as the real analysis. In the other, known as the hypothetic analysis, the combinations in which the elements or the acids and bases are supposed to exist, are reconstructed.

The hypothetic analysis cannot be exact, but is valuable from the standpoint of therapeutics, and constitutes the bases of the classification of mineral springs.

According to the *Annuaire des Eaux de France,* mineral waters contain a small number of acids and bases, which, as a rule, mutually saturate themselves. When the saturation is not complete the acids are present in excess. The acids that may be found are carbonic dioxide, hydrogen sulphide, sulphuric, hydrochloric, hydrobromic, hydriodic, nitric, phosphoric, and arsenious. The first three are most important. Among bases we have sodium, potassium, calcium, magnesium, lithium, and the protoxides of iron and man-

ganese. Sodium is present in nearly all mineral waters, generally as the predominant base; potassium very rarely preponderates.

The principal gases are carbonic dioxide, nitrogen, hydrogen, hydrogen sulphide, different forms of carburetted hydrogen, ammonia, and hydrochloric acid gas. The oxygen and a part of the nitrogen are probably derived from the atmosphere. The origin of the others has not been definitely determined.

Certain gases, by reason of their abundance and their influence upon the organism, form important ingredients of mineral waters. Such gases are hydrogen sulphide, carbonic dioxide, and probably also nitrogen. Many gaseous springs contain carbonic dioxide, both in the free and the combined state.

In addition to the commoner substances mentioned above, there are others of much rarer occurrence in mineral waters, as arsenic, salicylic, boric, hydrofluoric acid, aluminium, barium, strontium, copper, nickel, cobalt, titanium, rubidium, cæsium. Organic matters, generally playing the part of acids, may also be present.

Arsenic was discovered by Tripier, in 1889, in the thermal spring of Hammam-Meskoutine, in Algiers.

Since then it has been found in the water of Bourboule, Vichy, Mont-Dore, and others. According to Le Fort, it is derived from arseniferous ferruginous minerals.

Temperature. The temperature of mineral springs varies—some waters are cold, others tepid, and yet others warm; the latter being the so-called thermal springs. It should be noted at this point that the term thermal has a variety of meanings.

The French *Annuaire* considers a spring to be thermal when its temperature is appreciably above that of the mean annual temperature of its place of emergence.

Filhol applies the word to all springs having a constant temperature. Durand-Fardel makes the same divisions of springs as are made of baths, terming those having a temperature below 68°, cold; those having a temperature of from 68° to 86°, tepid; those the temperature of which is 87° to 96°, hot; and those having a temperature of 97° to 114°, very hot.

An important and interesting fact is the constancy of the temperature of mineral springs. Carrere, in 1754, determined the temperature of the springs in the Pyrenees, and Le Grand, ninety years later, obtained the identical figure.

Springs that have a deep origin are generally warmer than those

coming from near the surface. Solid strata and a rapid flow are factors that favor the conservation of the heat of a spring, while a porous soil or an intercallated lake or expanse of water tend to produce a variable temperature. As a rule, constancy of temperature is associated with the constancy of mineralization.

Unctuosity. Certain mineral springs particularly rich in organic matter have the peculiar property of *unctuosity*. In sulphur springs possessing this quality, Fontan and others have found various forms of microscopic algæ. The one discovered by Fontan, a delicate, filamentous alga, inhabits only sulphur springs having a temperature of 97° to 114°. It contains a small proportion of iodine.

Electric Condition. A number of springs are endowed with active medicinal properties which seem to be entirely independent of their chemical constitution. Scoutteten has proposed the theory that the effects are due to electricity. Gigot-Sward and Armieux have found that in sulphur springs the tension on the surface is positive, in the deeper parts negative. In their opinion the electric condition is due to the incessant modification of the element sulphur. Paul Benard confirms the results of Scoutteten's researches, but declares that there is not any relation between the electric reactions and the therapeutic properties of mineral waters.

Waltenhofen, of Gastein, has carefully compared the conductivity of medicinal waters with that of various potable waters, and has found that the former possess conductivity in a higher degree than ordinary drinking-water.

The data, however, are as yet insufficient to permit us to form any positive conclusions with respect to the part played by the electric phenomena in the therapeutic action of mineral springs. We may state the present status of the question as follows: Certain mineral waters of an indifferent chemical constitution appear to be in a peculiar electric state, by reason of which their influence upon the organism approaches that of the electric bath. In others the electrical condition is susceptible to change during the course of their employment, a peculiarity which endows such springs with properties differing markedly from those possessed by ordinary water.

The greater number of mineral waters undergo changes on exposure to the air: a part of the contained gases is disengaged and some of the salts are deposited. In the incrusting springs these salts are calcium compounds; in others, silica or iron is deposited.

Mud-springs. Mud-springs, the therapeutic value of which is

unquestionable, are of two varieties — the mineral and the vegetable.

Vegetable mud-springs are those which contain algæ, or are impregnated with decomposing organic matter. Such springs are found at Néris, Bourbon-Lancy, Bourbonne, Bagnères-de-Luchon, etc.

The Physiological and Therapeutic Uses of Mineral Waters.[1]

The use of mineral waters in medicine is founded entirely on empiricism: clinical observation and therapeutic results are even at the present time our only guides in their employment. In recent years, however, much has been done toward the attainment of a more accurate knowledge of the uses and actions of mineral waters, and the results attained give promise that the treatment will soon be based on scientific principles.

We may divide the treatment into the external and the internal. Although both are generally employed conjointly, the distinction is of value.

Effects of the Bath. The most typical of the external measures is the bath. It is capable, even when used alone, of producing marked therapeutic effects. Whether analogous results can be accomplished with ordinary potable water is a question that has often been discussed.

The differences that exist between the results at one station and those achieved at another, although the bath may constitute the principal element of the treatment in each, demonstrate conclusively that mineral waters possess a peculiar action of their own. These effects, however, are obtained in diseased persons, and are therapeutic rather than physiological. Physiological studies of value can only be made upon healthy subjects. Quite a number of authors have occupied themselves in recent times with researches of this character, and have secured data which we shall briefly outline in this chapter.

The experiments of Röhrig and Zuntz, as well as those of Beneke, have shown that salt-baths stimulate the activity of the skin and modify the nutritive processes. Keller's comparative studies also indicate clearly that there exists a noticeable difference between the action of the salt-bath and the ordinary bath; a result that is strongly corroborated by Gauly. Groedel has found that the salt-bath and

[1] The chapter on Thermic Agents should be read in connection with this chapter.

the simple bath do not influence the electric excitability of the body in the same way.

The ferruginous baths, according to Flechsig, have their special properties, and even the carbonated baths have been asserted to possess, by Jacob and by Stiller, qualities that distinguish them from simple baths.

Even those baths that are mineralized to an insignificant degree, such as Néris, which contains only 1.1445 grammes of solid to the litre, are capable of producing marked and peculiar effects.

Let us examine as to which factor or factors these effects are due. Is there any absorption of the mineral and gaseous ingredients of the waters, and will this absorption account for the therapeutic results?

A large number of investigators—Braun, Poulet, Rabuteau, Roussin, Parisot, Valentiner, Passaboc, Keller, and others—decide these questions in the negative, while others are convinced that it should be answered in the affirmative. Thus Delore, Duriau, Homolle, Hofmann, Villemin, Wolkenstein, and Stabel have proved that certain active substances, especially digitalis and potassium iodide, pass through the skin. But the quantity absorbed is very small, and this factor plays, probably, no *rôle* in the effects produced by the baths.

Yet, although the bodies in solution do not penetrate so far as the blood, they at least permeate the superficial layers of the skin. This imbibition on the part of the skin is favored by heat and by the removal of the layer of sebaceous matter normally present. It is most marked on the soles of the feet and palms of the hands, where sebaceous glands do not exist.

This imbibition does not of necessity imply absorption. Energetic friction performed during the bath may be able to cause the penetration of the medicinal substances into the ducts of the sebaceous or sudoriferous glands, or into the hair-follicles, and yet no real evidence may be found of any absorption. According to Aubert and Schott, the bodies in solution may even, without having been absorbed, permeate the integument as far as the terminal nerves, which approach nearer to the surface than the bloodvessels.

Perhaps this direct action upon the cutaneous nerves is in part the cause of the special influence of the baths.

The absorption of gases and volatile substances is much less in doubt. Hydrogen sulphide, iodine, and carbonic dioxide pass into the circulation, but only to a limited degree on account of the tension

of the gases of the lymph and blood. Some of the gases disengaged from the surface of the water may mix with the respired air and be inhaled and then absorbed.

Be this as it may, the total quantity of active substance absorbed through all channels is small, and the peculiar effects of the baths cannot be attributed to this factor.

We are, then, compelled to rely for the influence of baths upon the body through the medium of the nervous system.

Leichtenstein held that mineral thermal baths did not produce effects at a distance through the medium of the vasomotor or the pneumogastric nerves, but that the baths simply acted like the other procedures of balneotherapy. It is generally admitted, however, that there is a peculiar exciting action, and if this is not admitted the effects of the baths remain absolutely mysterious. The observations of Jacob confirm this; he found that a bath containing carbonic dioxide had an action on the heart differing from that produced by ordinary soft water.

The special effects may depend upon the physical properties of the water as well as upon the chemical. Certain writers ascribe them to electric conditions; others see an analogy between the effects of mineral water containing metallic substances in solution and the phenomena produced by the application of these metals to the surface of the body.

The temperature of the water does not constitute a special quality, but some influence must be accorded to the great constancy of the temperature, and perhaps also the perpetual renewal of the water of certain springs. Of considerable importance are the softness or hardness and the unctuosity of the water, and the irritant properties depending upon the presence of certain salts, as well as the disengagement of gas-bubbles from certain waters and their impingement on the skin.

It should also be added that the repetition of the baths, as is customary at resorts, brings about a summation of effects.

Whatever the essential factor, there can be no doubt that the baths at certain stations are capable of producing a distinctly pathological state—a form of thermic fever, characterized by general disturbance with malaise, by acceleration of the pulse, rarely by a transient elevation of temperature, and at times by cutaneous eruptions, which, however, in a number of instances, at least, is only the recrudescence of an old malady. This thermic fever is noticed, as

a rule, after the twelfth bath, and, if mild, it has a favorable prognosis.

Effects of Mud-bath. The subject of mud-baths may properly be considered under the head of mineral springs. There are three resorts in France where such baths are given—Barbotan, Saint-Amand, and Dax.

The treatment in vogue at these places consists of the immersion of the body, for a variable period, in mineralized slime, maintained at a constant temperature. This is followed by a simple bath for cleansing the skin.

The mud-baths may be employed in the form of general or of local applications.

In Germany the mud-baths (*schlammbäder*) are extensively in use. At certain places, such as Franzensbad, the mud is prepared artificially by mixing a fine loam with mineral water. Lake Balaton-Füred, in Hungary, furnishes a grayish slime containing an abundance of silicate of lime crystals, which produce a certain degree of friction of the skin.

The physiological effects of the mud-baths are not well understood. The dense or massive baths appear to act, in part at least, by the pressure which they exercise upon the skin, and by driving the blood from the periphery to the central parts of the body. An impediment is thus offered to the establishment of the thermic equilibrium between the body and the bath, and consequently the temperature of the blood is not lessened, although that of the bath is low. Jacob has even noted an increase in the central temperature, no doubt attributable to a retention of heat. For the same reasons the mud-bath at a high temperature is more easily supported than a bath in water of the same temperature.

According to Fellner, some influence is to be ascribed to the presence in the bath of mineral salts.

When the temperature of the bath is equal to or lower than that of the skin, the pulse and respirations are decreased in frequency, while the cutaneous perspiration and the excretion of urea are augmented. The mud-baths can be prolonged to a much greater length than the ordinary baths. They do not produce relaxation of the skin or sweating.

With the exception of Barbotan, the baths of which are sedative to rheumatic patients, the mud-baths are, as a rule, stimulant to the skin and have a resolvent effect.

At Franzensbad the stimulation is intense, the application being followed by a vivid and persistent redness of the skin. This, indeed, is the case at the majority of resorts, notably at Balaton-Füred, the silicated baths of which produce a distinct erythema.

At some stations the therapeutic effect is probably in part due to the respiration of air charged with sulphur. This is an important factor in the influence of the baths of Saint-Amand.

The topical applications made with the confervaceous algæ that grow in the basin and pools of mineral water constitute a special form of treatment.

At Néris, at Bourbon-Lancy, and at Valdieri, Italy, these vegetable substances serve especially for the purpose of practising friction, which may be combined with massage.

In some instances, as at Néris, the conferva enclose crystals of calcium carbonate, which intensify the effect of the friction.

Effect of Douches. The douche of mineral water exercises, like the bath, a peculiar effect, which is equally difficult of explanation. The mode of application, and the more or less frequent repetition, no doubt contribute to this effect; but they are factors common to the other hydrotherapeutic measures. (See Hydrotherapeutic Measures and Thermic Agents.)

In certain localities the chambers in which the douches are given are filled with vapors and gases that are in part absorbed through the air-passages. This factor probably plays a *rôle* in the production of the therapeutic effects. At Bagnères-de-Luchon, Filhol found free sulphur and hydrogen sulphide in the atmosphere of the douche-chamber, and he estimates that during a sojourn of a quarter of an hour an individual inspires 82 litres of air containing 1.40 c.cm. of hydrogen sulphide. At Barèges the air in the apartment contains 3 per cent. less oxygen than the general atmosphere. At other resorts the carbonic dioxide is in excess, while at still others a deposit of free particles of sulphur occurs on the skin. These various peculiarities assist us in understanding the variability of the effects obtained with measures that are apparently similar in character. When the douches are applied to a mucous membrane, as that of the vagina, the rectum, the conjunctiva, and the pharynx, the absorption of medicinal substances undoubtedly adds its effects to the topical action of the water.

Inhalation. During recent years the inhalation of mineral water vapors has become one of the most important therapeutic measures.

In reality it may be considered as a form of internal treatment. Several factors combine to produce the effect derived from inhalation—the watery vapor, the heat, and the modification in the respired air, the last consisting in an alteration of the proportion of gaseous constituents in the addition of foreign gases, or in the suspension in the air of saline particles or of organic substances capable of penetrating with the air into the lungs.

In Germany the inhalation of gases and vapors disengaged from sulphur waters has long been in vogue. Patients have also been sent into the drying-houses and evaporating-rooms of salt factories that they might inspire the salt-laden atmosphere. The first inhalation-chambers in France were established sixty years ago at Mont-Dore by Bertrand, to whom the idea had been suggested by a patient suffering from asthma, who attributed his cure to the vapors arising from the springs.

Thénard and Lefort found saline particles and an arsenical salt in the vapor of the chambers at Mont-Dore, and Nicolas recently established the fact that in these chambers the proportion of carbonic dioxide is sixty times greater than in the air.

Traces of saline particles and of organic substances have been found in the water of condensation in the chambers at Plombières. Analogous observations have also been made by Petit at Vichy.

At Royat the atmosphere of the inhalation-chambers is said to contain carbonic dioxide, soda, sulphuric acid, and organic matter (Nivet). At La Bourboule special contrivances have been devised by means of which the mineral water itself is transformed into a spray, and as such pervades the atmosphere. This has also been done at Ischl, where chloride of sodium produces the effects.

At other stations the atmosphere contains only those vapors that arise spontaneously from the waters at the temperature of the air.

Inhalation of Salt Air. The inhalation of salt air is a special feature at several German and Austrian watering-places. The waters, which are more or less rich in sodium chloride, are conducted by means of hydraulic machines to the upper parts of an apparatus consisting of bundles of dried twigs superimposed upon one another. These are the *Gradiswerke* of the Germans. The waters run through pipes that are disposed on all sides, and which, being pierced by lateral holes, permit the water to fall upon the fagots. As the water descends over the smaller twigs it is broken into fine

drops, which lower down are still farther subdivided and eventually become volatilized.

During the progress of the evaporation the air becomes impregnated with certain principles and its chemical constitution is altered. The patients inhale this air daily for a variable number of hours. It differs from the ordinary atmosphere in possessing a peculiar freshness, in having a higher density and a greater proportion of oxygen and perhaps of ozone. It is more or less saturated with the vapor of water and encloses a notable quantity of sodium chloride as well as traces of iodine and bromine. The carbonic dioxide seems to be present in a smaller proportion than it is found normally.

The effect of the salt air is sedative and manifests itself in a slowing of the pulse and in a diminution of the respiratory movements, which, however, have a greater amplitude.

At certain watering-places the atmosphere of the inhalation-chambers is modified by the playing of one or more fountains.

Inhalation of Hydrogen Sulphide. A considerable quantity of hydrogen sulphide is emitted from many sulphur springs. Since 1845 inhalations of this gas have been given at Amélie-les-Bains and at le Vernet. The patient can remain in the inhaling-rooms for several hours without experiencing any discomfort. Respiration is not impeded, but the circulation is somewhat slowed.

At Allevard the gas given off from the sulphur springs contains in every litre, hydrogen sulphide, 24.75 c.cm.; carbonic dioxide, 97 c.cm.; nitrogen, 41 c.cm. To secure the escape of these gases the water is allowed to fall over a number of superimposed vases. The patients do not disrobe to enter the inhaling-chambers; after a sojourn of several hours a slight headache develops, which, however, disappears promptly on returning to the fresh air. The effect of the inhalation at Allevard is sedative. At Saint Honoré the hydrogen sulphide is made to mingle with the air by means of an ingenious apparatus devised by Collin. The effect is primarily sedative, but after a time becomes stimulating.

Baths of hydrogen sulphide have also been employed. They are administered in chambers analogous to those used for vapor-baths, and have a calmative influence upon the nervous system and the circulation.

The Use of Carbonic Dioxide. The gas, the application of which is the most varied, is carbon dioxide. The idea of its use in medicine was conceived in France in 1834, by Goin, at Saint Alban, who

devised apparatus for employing it in diverse ways. Its therapeutic value has been thoroughly investigated in Germany, where numerous stations have adopted its use, such as Marienbad, Carlsbad, Meinberg, Cronthal, Eger-Franzensbad, Canstatt, Kissengen, and Nauheim. Of French resorts employing the gas we may name Saint Alban, Celles, Saint Nectaire, Vichy, and Royat.

The gas, emerging from fissures in the earth or escaping from springs, is used either in the pure state or mixed with the atmospheric air or hydrogen sulphide, or with the vapors of the mineral springs.

It may be employed in the form of baths, douches, or inhalations. The baths are administered in special bath-rooms. The head remains in the normal atmosphere, the latter being frequently renewed. Boxes similar to those used for ordinary vapor-baths may also be employed. The patients generally are lightly clad, and cover themselves with warmer clothing on leaving the bath.

The duration of the bath is from ten to twenty minutes. Local baths are given by means of the apparatus used for the ordinary partial baths.

For the administration of douches and injections into cavities the gas is conducted through rubber tubes terminating in special nozzles. The delivery of the gas is regulated by means of stopcocks. The nozzle in the case of the uterine and vaginal douche is passed through a fenestrated speculum which fits into a rubber pad so arranged that it prevents the escape of the gas.

By means of special contrivances, douches may be directed against the eyes, into the ears, and into the nasal fossæ.

For purposes of inhalation the carbonic dioxide should be mixed with atmospheric air, in the proportion of 5 to 8 parts to 100 of air.

Special methods are necessary to obtain the proper mixture.

A crude method consists in the inspiration of the gas through a tube from a gasometer or directly from its source, while pure air is simultaneously inspired through the nose. In other cases the gas is introduced into the open mouth and there mingles with the air. These modes of inhalation are fatiguing, and also do not permit exact dosage of the gas.

In localities where the inhalations are systematically practised they are given in well-closed chambers, to which the gas is carried in tubes. Small apertures in the conducting tubes permit the escape of the gas and its diffusion through the atmosphere.

The dosage is controlled by means of stopcocks and valves. Quite frequently the air is rendered moist by a jet of water or by steam. Every care is taken to prevent the presence of carbonic dioxide in excessive amounts. The *séance* is short, about ten minutes, being progressively lengthened to twenty minutes.

The physiological properties of carbonic acid are well marked. A stream projected against the skin first causes a sensation of coolness, then one of warmth, and, finally, almost complete anæsthesia. Similar phenomena are developed when the body is exposed to an atmosphere of CO_2, the respiration at the same time being carried on in the free air. Sweating may also be produced. According to Paalzow and Pflüger, the baths do not augment the nutritive processes. The ability of the skin to absorb carbon dioxide renders the use of the baths not entirely devoid of danger; their administration should, therefore, be supervised.

Röhrig has found that animals may be killed when immersed in an atmosphere of CO_2, although they are breathing the normal air.

In places where the treatment is systematically pursued, the following phenomena are normally observed:

There is at first a transient pricking sensation (*picotement*) of the skin, and at times pruritus ani; then follows a feeling of heat, and the skin breaks out in a copious sweat; there is also a desire to urinate, a certain degree of genital excitement, and an acceleration of the pulse.

When the proportion of carbonic dioxide does not exceed 15 to 30 parts in 100 the bath produces a general stimulation of the system; but when too prolonged it gives rise either to a state of excitement or to one of fatigue and prostration.

The inhalations are more dangerous. Carbonic dioxide is, indeed, a very poisonous gas, and when present in the atmosphere to the amount of 1 part in 100 is productive of more or less serious consequences. When the proportion is greater and the respiration of such an adulterated atmosphere is long continued, the blood becomes surcharged with CO_2. After a brief stage of excitement paralytic and asphyctic phenomena develop.

For these reasons the physician should carefully superintend the inhalation. On account of the dangers incident to their use the injection of gas into mucous cavities has been abandoned. At present the baths represent almost the only method in which carbonic dioxide is utilized.

The Use of Nitrogen. In recent years the attempt has been made to use the nitrogen which is contained in certain mineral waters for therapeutic purposes.

Nitrogen is commonly regarded by physiologists as an inert gas; it is not deleterious, but simply unfit for respiration. Nevertheless it possesses some physiological properties. It is not readily soluble in water; 25 c.cm. in a litre—while blood holds in solution ten times this amount. It is the red corpuscles that possess themselves of it, for the serum, according to Fernet, does not dissolve it. The analyses of the blood-gases, made by Magnus, have shown that there is more nitrogen in arterial than in venous blood, a fact which seems to indicate that a certain quantity of the gas enters into the circulation during the respiratory act. Liebig, Regnault, Planer, and Paul Bert have, indeed, admitted that the atmospheric nitrogen is to a slight extent absorbed by the lung. According to Regnault and Reiset, the nitrogen of the blood is derived from the atmosphere and from the nitrogenous food-stuffs. Reiset even believes that the skin is capable of absorbing a small proportion of the gas.

That the atmospheric nitrogen plays an important part in vegetable physiology, especially in the processes of nutrition, can no longer be doubted. Abundant proofs have been brought forward by the valuable labors of G. Ville and of Berthelot. But regarding animals and man the evidence of an influence on the part of nitrogen upon metabolism is very limited. In spite of this, nitrogen is now quite extensively employed as a therapeutic agent.

Its medicinal properties have been investigated by Nysten, and very thoroughly by Lecomte and Demarquay, Lemoine, and Steinbruck.

Inhalations have been used especially in phthisis, the patient respiring an atmosphere to which from 2 to 7 per cent. of nitrogen has been added. The first account of the results achieved was given by Mermagen, in 1880. When the treatment was confined to inhalations of nitrogen and the ingestion of nitrogenous waters the results were not marked.

The principal studies of the method have been made by Rohden, Hörliny, Brügelmann, and Zuntz, and by Spanish physicians at Penticoza, Urberoaga, and Caldas di Oviedo. Of the Spanish writers, Arnus and Garcia Lopez deserve special mention.

The nitrogen treatment has been highly developed at Lippspringe and at Inselbald, where the water at the moment of its transfor-

mation into spray by flowing over fagots gives off its gases to the atmosphere in which the patient breathes.

The systemic effects are sedative; the pulse becomes slower and softer, respiration easier; the temperature tends to fall, cough and expectoration diminish, the nervous irritability lessens, and sleep improves. To secure the best results no more than 7 per cent. and no less than 2 per cent. of the oxygen should be withdrawn from the air. In the atmosphere thus lightly rarefied the lungs are subjected to a mild form of gymnastic exercise. Whether the nitrogen itself has any medicinal properties is uncertain, and the question is certainly still *sub judice*.

Humage, Aspiration, Suction. A method somewhat analogous to inhalation is that known as *humage*, *aspiration*, or *suction*. It was first proposed by Lambron, at Bagnères-de-Luchon; at present it is in use at several resorts. The patient, by means of an appropriate mouth-piece, aspires or inhales from a reservoir the gases, spontaneously disengaged from the mineral springs, mixed with the atmospheric air.

The effects produced by this practice have not been fully investigated.

Atomization. The method of atomization consists in causing solutions of medicinal substances to enter the respiratory passages in the form of a fine spray. It originated at the sulphur springs of Lamotte-les-Bains. Since the invention of portable apparatuses the method has become an important element in ordinary therapeutics, and is now applied to the use of medicinal solutions apart from mineral waters.

It is unnecessary to describe the multiform apparatuses that have been devised for securing the atomization of fluids. Most important is the question of the value of the method.

In the first place we may ask, Do mineral waters subjected to atomization conserve their properties?

Of the sulphur waters which are most commonly employed for the purpose, some are markedly modified, others scarcely at all.

The second point concerns the penetration of the atomized liquids into the air-passages.

A commission, appointed by the Society of Medical Hydrology, after some experimentation, concluded that a small quantity of the spray enters the respiratory tract, a conclusion that has been confirmed by more recent researches. Waldenberg estimated the quan-

tity entering the bronchial tubes during an atomization of one minute as ten to fifteen drops. It is scarcely possible to ascribe any therapeutic action to such a dose. Nevertheless this small amount suffices for the production of changes, not only in the pharynx and larynx, but also in the trachea and the larger bronchi. The method, like that of inhalation, is employed almost exclusively in pulmonary diseases. Its most striking influence is upon the secretions and the nervous system; it diminishes cough and dyspnœa, facilitates expectoration, and modifies its character.

The method of irrigation of the nasal fossæ with mineral waters, according to the procedure known as Webers' douche, should be mentioned before closing this part of the subject.

Internal Use. By far the most important mode of employing mineral waters is their ingestion internally. They are generally taken in definite quantities, in the intervals between meals, on an empty stomach. The effects depend upon a number of factors, the principal of which are the quantity, the temperature, and composition of the water ingested.

When the water is strongly mineralized the patient takes a complex medicament in a more or less diluted state. At many watering-places the mineralization is feeble, sometimes even less than in the potable waters. It is best on this account to distinguish in the treatment the common effects, those attributable to the ingestion of water and the special effects arising from the peculiar composition of the water.

Without attaching too much importance to this distinction, it will be important, from the standpoint of the physiological study of mineral waters, first, to inquire into the effects produced by the ingestion of a quantity of plain water. Despite its apparent simplicity the question is far from being solved.

Two factors need to be considered in our inquiry—the mass or quantity and the temperature.

It is generally admitted that water taken into an empty stomach disappears rapidly; a part is absorbed, another is propelled into the intestines. What is the proportion that is absorbed? How rapidly does absorption take place? Very little is known on these points with regard to healthy man. In disease, however, the ingestion of water indubitably presents at times considerable variations, which should be investigated by the physician prior to adopting a plan of treatment. The gastric absorption of water appears to be regulated

in part by the phenomenon of osmosis, in part by the muscular functions of the stomach. The conditions governing osmosis, quite constant, we may suppose, in health, are, without doubt, very variable in pathological states accompanied by modification in the structure of the stomachic mucous membrane or in the composition of the blood. As regards the rapidity of the evacuation, it may be stated that certain stomachs empty themselves of their liquid or solid contents with great celerity, while others retain both for a long period of time.

There are patients who can ingest large quantities of fluids without producing gastric distention; others, on the contrary, experience pain when they introduce relatively small quantities, even very slowly, into their stomachs. In the latter there is often dilatation; and in all of them abnormal conditions of functional activity of the stomach can usually be recognized.

The influence of the temperature is not definitely known, although the belief prevails that tepid or warm water is more readily tolerated than cold.

It is very important to remember that even in perfectly normal conditions pure water when ingested excites a certain degree of glandular activity, and, in consequence, true digestion. This subject has so far been studied scientifically only in the dog, in the work of M. Winter and the writer.

The intra-stomachic processes are doubtless modified by the addition of a small quantity of salines to the water ingested. Several physiologists, among them Beclard, state that the presence of 2 per cent. of sodium chloride suffices to render the absorption of the water more difficult. This is practically the sum total of our knowledge on this interesting and complex question, which deserves diligent study, since in mineral waters we have represented solutions of saline substances.

Such solutions are capable of modifying the osmotic processes as well as the glandular action, the modifications depending upon the proportion of materials in solution. We shall revert to this subject when considering waters in detail. Arrived in the intestines, the water continues to be absorbed. But as intestinal absorption proceeds slowly, the water may, if in sufficient quantity, exert a laxative or purgative effect even when it contains not a trace of any purgative salt. Cold water is in this respect more active than hot, although water slightly warm is equally capable of exciting intestinal peri-

stalsis. At some resorts, the waters of which are feebly mineralized, the patients can drink without discomfort 2 or 3 litres in the space of 24 hours.

Bouisson has claimed that in animals which are forced to drink large quantities of water the portal vein becomes turgescent. Böcker admits that the absorption of water dilutes the blood, but the change is transient, scarcely enduring longer than fifteen minutes, even after the ingestion of a large quantity of water. In attempting to determine the dilution of the blood by estimating the quantity of hemoglobin by means of the spectrophotometer, Leichtenstern failed to note any changes after the consumption of a quantity of water. We may conclude from these researches that the blood disposes rapidly of an excess of fluid. The discharge is chiefly by the kidneys. The diuresis varies with the temperature of the water; it is more active under the use of hot water, and diaphoresis takes place at the same time. It is likewise influenced by atmospheric conditions, being greater when the weather is cool and moist than when it is hot and dry. When flushing of the kidneys is desired it would, therefore, be a palpable error to send the patient to the watering-place during the hottest period of the year.

The kidney is not the only organ charged with the elimination of water. In proportion as the latter enters the blood it diffuses itself through the entire body and acts probably on all the tissue elements. It may therefore modify all the secretions and excite disturbances of nutrition.

Ferber, Mosler, and Weyrich have observed an increased loss of substances through the skin, more marked after the ingestion of hot than after cold water. Lehmann records the stimulation of the parotid secretion; Weimann that of the pancreas; and Bidder and Schmidt, Nasse, Arnold, and Röhrig that of the biliary secretion.

The study of the fluctuations in blood-pressure have not yielded concordant data. Thus Winternitz holds that hot water diminishes the pressure of the blood; Kisch that it increases the pressure. The ingestion of cold water diminishes the frequency of the pulse, but this effect is transient. It is without doubt due to an influence upon the branches of the pneumogastric nerve, for it is noticeable before the fall of temperature consequent upon the internal cooling manifests itself.

Unquestionably the most important effect of the ingestion of water is that exerted upon the nutritive processes. Although the exact

determination of the extent and character of this effect is not easy, it has been much elucidated by studies upon the variations of the urine and of the body-weight.

The majority of experimenters have found that the urinary losses are augmented. Genth, Mosler, Becquerel, Chossat, Lehmann, and Falk have observed that in addition to diuresis there is an increase in the elimination of urea, of sodium chloride, and of phosphoric and sulphuric acids.

The consumption of from 2 to 4 litres of water increases the excretion of urea about one-fifth. Recent observations have yielded similar results, at least as regards the nitrogenous elimination. Debove and Flamant are almost alone in their denial of an increase in the excretion of urea.

The increase in the elimination of nitrogen has been interpreted in various ways. J. Mayer and others, whose experiments were made on animals, believe that the ingestion of a quantity of water produces a sort of general lavage of the organism, whereby the waste-material retained in the tissues is washed out. Others, as Robin, while not denying this factor, hold that there is an increased oxidation. This is plausible enough, if it is true, as Bordel claims, that the weight of minerals diminish when the dietetic regimen remains unaltered and increases when no restriction is placed upon the appetite.

Genth and others have asserted that the uric acid disappears from the urine after the ingestion of large amounts of water. But Schöndorff, by employing for the determination of the quantity of uric acid the method of Salkowski as modified by Fokker, was unable to observe any influence upon the elimination of uric acid.

Whichever of these various divergent views be correct, we can safely say that the ingestion of water seems to stimulate intra-organic activity. To this most important influence is added the therapeutic effect produced by the constituents of the different waters.

At places where the water is deficient in mineral ingredients, therapeutic results are obtained by the ingestion of large quantities of water. At others, where the water possesses medicinal properties, small or even relatively insignificant quantities may suffice for the production of therapeutic effects.

The mode of employment of the waters must, therefore, be varied, and patients should not be allowed to drink as they list. Nothing is more frequent than the accidents due to the abuse committed in this respect by patients.

It is impossible to lay down fixed rules regarding the treatment; every patient should receive individual study. We shall only append a few general remarks.

As regards dosage, medical practice has been greatly modified in recent years. The large doses formerly prescribed are now considered dangerous or unnecessary. The fact that smaller quantities suffice is explained by some of the older physicians by assuming that the contemporary class of patients is less robust and lest resistant than that of former generations.

The active dose varies from two to four glasses a day. It is customary and wise to begin with a small quantity and increase gradually. This precaution is important, since some of the waters contain sufficient gas to produce symptoms of intoxication.

Some of the waters, of feeble mineralization, can be ingested in very large doses. These are the so-called lavage-waters, among which are those of Contrexéville, Vittel, and Evian.

The amount is generally prescribed by the glassful. For this reason it is evidently very important that all stations make use of a standard glass, graduated in the decimal scale. More precise ideas of the results achieved by the waters can then be obtained.

As a number of mineral waters can be transported to a distance, the question has frequently presented itself whether it is indispensable to success that the waters be drunk at the springs or whether the treatment can be carried out at the patients' homes. We are confronted in regard to this point by the conflicting statements of the companies which solicit the employment of transported waters, and of the resident physicians whose existence is endangered if the patients do not visit the springs to drink the waters. The latter insist that the waters, even in cases in which the chemical analysis demonstrates that they are not modified by transportation, have special properties when consumed at their source, and that they do not possess these when taken at the patients' homes. It is not necessary to mistrust the physicians' statements because they are interested; indeed, we believe their opinion is well founded, and are convinced of the superiority of "the cure" *in situ*.

But we do not ascribe the advantage to any mysterious qualities of the water at the springs, which it loses when bottled. Many factors, foreign to the quality of the water, are present in the treatment carried out at watering-places, and it is to these accessory factors, as they may be termed, that much importance must be attributed.

Classification. Europe, and particularly France, is rich in mineral waters possessing a most varied composition and a great diversity of therapeutic properties. It is obviously essential to adopt some classification for the better study of the multitude of remedies which Nature has prepared for us. Many classifications have been proposed, the best being those in which the waters are considered as drugs capable of producing certain therapeutic effects. The difficulties in thus classifying the waters are great, by reason of the complexity of many of the latter, and the insufficiency of precise facts in regard to the elements upon which the effects depend. The classifications, since that of the *Annuaire des Eaux minerales de la France,* have been subjected to many changes. It was Durand-Fardel who first attempted to group mineral springs in such a way as to emphasize the relationship existing among certain classes from the point of chemical and therapeutic properties. His principle is the only one which, in the present state of our knowledge, meets the exigencies of practice.

Without deviating sensibly from the divisions established by Durand-Fardel and adopted by the majority of specialists, we shall make a few changes.

Classification of Mineral Waters.

Groups.	*Classes.*
I. Sulphurous and sulphuretted waters	Sodium sulphide waters. Calcium sulphide. Sulphuretted and chloride waters.
II. Sodium chloride waters	Pure sodium chloride waters. Mixed sodium chloride { Sulphuretted. Carbonated.
III. Sodium bicarbonate waters.	
IV. Alkaline waters or calcium waters.	
V. Sodium and magnesium sulphate waters	Pure sulphates (bitter springs). Mixed Sulphates.
VI. Ferruginous waters	Carbonated. Sulphates.
VII. Undetermined waters	Simple mineral springs. Acid gaseous springs.

Complementary Groups.

Arsenical waters, iodine and bromine waters, lithia waters, nitrogenized waters.

In order to gain a systematic knowledge of the properties of these waters, it is advisable to begin our study with those the constitution of which is most simple. The mixed waters, having qualities depending upon several principles, cannot be correctly understood until

the simpler ones have been investigated. Thus, for example, the study of the sulphuretted chloride waters presupposes a knowledge of the simple sulphuretted and simple chloride spring.

The order in which we shall pursue our study is as follows:

A. Waters in which the action of one principle or of a group of analogous principles predominates. Waters relatively simple.

I. Sulphuretted waters (sodium or calcium sulphide).
II. Sodium chloride waters.
III. Sodium bicarbonate waters.
IV. Alkaline earths or calcium waters.
V. Sodium and magnesium sulphate waters.
VI. Ferruginous waters.
VII. Undetermined (simple mineral and acid gaseous waters).

B. Waters the therapeutic effect of which seems to be founded on the presence of several principles.

Mixed or complex waters:

1. Sulphuretted chloride or chloride sulphuretted waters.
2. Chloride bicarbonate waters.
3. Mixed sulphate waters.
4. Complementary groups: arsenical waters, iodine and bromine waters, lithia, and nitrogenized waters.

Sulphur Waters. In considering the sulphurous or sulphuretted waters we are at once confronted by some of the most difficult problems of medical hydrology.

The sulphur waters are remarkable for their complex composition, although in the majority the sum of mineralizing principles is very small.

The chemical element which characterizes them all is sulphur. It is nearly always present in a form capable of producing, in small doses, relatively potent effects, and is associated with other principles which may synergize or attenuate and modify its action.

Sulphur may exist in the form of hydrogen sulphide or as an alkaline sulphide (of sodium, calcium, magnesium, and potassium). Apart from it, sulphate of calcium, chlorides, carbonates, and silicates are also present, as well as organic matter and gases; carbonic dioxide and nitrogen; sometimes traces are found of iron, of iodides and bromides. A large number of sulphur springs are hot, others are cold. Several authors have made this character their base of classification, but in spite of its interest the temperature appears to us a factor of not sufficient importance to warrant such a division. It is

more rational to base the classificatiou upon the manner or character under which the element sulphur presents itself.

The most simple division, that of Durand-Fardel, comprises only two great classes—the sodium sulphide and the calcium sulphide or sulphuretted hydrogen waters. Le Bret distinguishes five classes—sodium sulphide, sodium sulphide and hyposulphite, calcium sulphide, hydrogen sulphide, sodium sulphide and chloride springs. It seems to us that, following the example of Durand-Fardel, we may place the hyposulphites with the sodium sulphides, and the hydrogen sulphides with the calcium sulphide springs.

We have, then, the following three classes: Sodium sulphide springs, calcium sulphide and hydrogen sulphide springs, sulphuretted chloride springs. These have, however, certain important subdivisions to be subsequently indicated.

Sodium Sulphide. The sodium sulphide waters are those the principal mineral constituent of which is sodium sulphide. They are at the same time the most abundant, and, from the therapeutic standpoint, the most important waters. The majority are warm springs. They are found principally in France, where they are distributed in two geographic groups of unequal value. The first, by far the most important, occupies the foot of the Pyrenean chain; the second is situated near to the Dauphin Alps and Savoy. A few are also found at other scattered points.

Sulphur is always present in very small quantity, not exceeding even in those most rich in it (Luchon) 0.077 gramme per litre. The form under which it exists is still an obscure problem.

Without referring here to those springs which contain hydrogen sulphide in the presence or absence of sodium, and which do not properly belong to the class under discussion, we find in the sodium sulphide springs proper sometimes a monosulphide (Filhol), sometimes a disulphide (Garrigou, Duhourcau). In the majority Berthelot found the sulphide of an alkali, hydrogen sulphide, and free alkali (sodium). These dissimilar results seem to arise from a changeability of many of the waters—a changeability depending upon the complexity of their composition. The elements found in them are capable, under certain conditions, of altering their original state. Their appearance at the surface, the fall of the pressure to which they were previously subjected, the disengagement of gases, the change in the organic constituents, all these factors produce with more or less promptness chemical mutations.

Returning to the principal points, according to the excellent description of Durand-Fardel, we find that the chemical changes produce the following results: They cause disengagement of hydrogen sulphide, which ceases only when a hyposulphite is formed; and generally the alkaline sulphur waters are decomposed in giving birth to polysulphur compounds, to hyposulphites, to sulphites, and sulphates. Polysulphuration is generally a transient phenomenon, but it may persist, as at Barèges, and be a factor in producing special therapeutic properties. In some cases a small quantity of sulphur is set free, and, remaining in suspension, gives to the water a peculiar color—at times white (Luchon), at times blue (Ax). In certain springs the decomposition takes place rapidly, and gives rise to modified waters possessing special properties.

Durand-Fardel believes that in practice the degree of alterability of the sulphur water should be taken into account rather than their percentage of sulphur. Besides the relative stability of the sulphur, the greater or less disengagement of hydrogen sulphide, polysulphuration, and the presence of sulphites should be considered.

The quantity of sulphur is estimated by the sulphydrometric method of Dupasquier.

The method depends upon the fact that when an alcoholic solution of iodine is added to a sulphur water containing a little starch, the blue color does not appear until every trace of sulphur has been decomposed. The blue color persists from the moment all the compound sulphur has disappeared (Pelouze). As one equivalent of iodine replaces one of sulphur, it is only necessary to use a standard solution.

The best sodium sulphide springs are all found in the Upper and Lower Pyrenees. They issue from primitive rocks, or from those at the limits of the primitive and transitional strata. Nearly all of them are warm; they all give an alkaline reaction, and contain a nitrogenous organic substance which appears to have some share in the effects. Their odor at the source of the spring is distinctly sulphurous.

The changeable waters—*i.e.*, those containing carbonates, hyposulphites, sulphites, and alkaline sulphates—have also an alkaline reaction, but possess neither an odor nor a taste of sulphur. They contain, like the others, a trace of organic matter, and are found, especially in the eastern Pyrenees, issuing from granitic strata of rock. They form the class of sulphuretted hyposulphite springs of Le Bret.

SULPHIDE WATERS.

Stations.	Name of springs.	Sulphide of sodium	Free H_2S.	Silicates.	Organic matter.	NaCl.	Total	Temp
Bagnères-de-Luchon	Bayen,	0.077	traces	0.022	......	0.082	0.227	71.5°
	Grotte supérieure,	0.031	traces	0.057	......	0.072	0.249	54.5
Cauterets . . .	César,	0.023	...	0.111	0.045	0.071	0.260	48.2
	La Raillière,	0.017	...	0.040	0.035	0.059	0.219	58.7
	Mauhourat,	0.016	azote	0.108	0.046	0.080	0.258	50
Barèges . . .	Tambour,	0.040	..	0.116	0.066	0.072	0.296	44.1
	Entrée,	0.034	...	......	......	0.050	...	43.9
	Barzun,	0.033	...	0.106	......	...	...	30.5
Eaux-Bonnes . .	Source Vieille,	0.021	...	0.031	0.048	0.261	0.571	32.7
Saint Sauveur . .	Des Dames,	0.021	...	0.086	0.032	0.069	0.250	35
Eaux-Chaudes . .	Le Clôt,	0.008	traces	0.030	......	0.089	0.314	36.2
Ax.	Viguerie,	0.020	...	0.129	0.045	0.035	0.261	73.5
Le Vernet . . .	Ursule,	0.012	...	......	......	...	0.250	42
Amélie-les-Bains . .	Amélie,	0.025	...	......	0.014	0.016	0.273	47
Moligt	....	0.014	...	......	0.007	...	0.158	37
Olette	....	0.028	...	......	0.034	0.031	0.401	75
La Preste . . .	....	0.012	...	......	......	...	0.242	40–42
Cold springs:								
At Bagnères-de-Bigorer	Labassère,	0.032	...	0.055	0.145	0.205	0.545	12.5
Gazost	....	0.031	...	......	......	0.319	0.479	12
Saint Boès . . .	....	0.130	...	......	0.164	...	3.443	12
Marlioz	....	0.020	...	......	......	...	0.510	14

The following is a description of the water at the springs of Challes:

Temperature	9.5°
Sulphydrometric test	0.217
Nitrogen	24 c.cm.
Sulphite of sodium	0.35900
Bromine	0.00375
Iodine	0.01235
Total	1.21850

Beside the French resorts of this class we should mention Mehadia, in Hungary, which is warm; Lostorf, Stachelberg, Heustrich, in Switzerland, and Hohenstadt, in Bavaria, which are cold.

Calcium Sulphide and Hydrogen Sulphide Springs. The calcium sulphide and hydrogen sulphide springs are mineralized by calcium sulphide or by free hydrogen sulphide. The former are generally cold; the latter are either cold or warm. In addition to the sulphides, the waters also contain saline substances—sulphates and chlorides—in solution. They are less alkaline than the preceding group. The following are the French springs of this class; Aix-les-Bains and Saint Honoré, which are warm; Enghein, Pierrefonds, and Allevard, which are cold. Switzerland has Schinznach (warm), Lenk, and Gurnigel (cold). Trencin-Teplitz, in Hungary, Langenbrucken, in Baden, and Neundorf, in Prussia, should also be mentioned. The springs of Schinznach, in Switzerland, and of the

Waldquelle, at Langenbrucken, are remarkably rich in free hydrogen sulphide.

CALCIUM SULPHIDE AND HYDROGEN SULPHIDE SPRINGS.

Stations.	Sulphide of calcium.	Free H_2S.	Sulphate of sodium.	Chloride of sodium.	Total.	Temperature.
Warm springs:						
Aix-les-Bains (sulphur) .	....	0.003	0.092	0.030	0.493	44°
" " (alum) .	....	0.203	0.081	0.027	0.446	47
Saint Honoré . . .	0.032	0.070	....	0.305	0.671	30–33
Schinznach . . .	....	135.9 c.c.	0.15	....	....	36
Trencin-Teplitz . . .	....	15.0	1.00	0.17	....	40
Cold springs:						
Enghien (du Nord) . .	0.118	....	0.275	0.048	0.900	12
Pierrefonds	0.015	0.002	0.020	0.020	0.349	10
Allevard	....	24 c.c. 75	0.298	0.503	2.235	10.7
Langenbrücken, Baden (Waldquell) . .	....	165.7	0.12	0.01	....	13
Lenk	....	44.5	1.65	....	....	8
Neundorf	....	39.3	0.36	1.01	....	11
Gurnigel	0.004	15.1	1.30	....	....	8

PHYSIOLOGIC EFFECTS OF SULPHUR WATERS. The action of sulphur waters is due particularly to the hydrogen sulphide and the alkaline sulphides present.

The reputation of sulphur is quite ancient; it was called *balsamum pectoris*, and was considered to be a diaphoretic and a deobstruant of the portal vein, as well as a purgative and alterative. It has lost much of its pristine renown.

Hydrogen sulphide, H_2S, is a poisonous gas, capable of exercising harmful effects, even in small doses, especially when it penetrates into the economy by way of the respiratory tract. Claude Bernard has shown that when it is absorbed by other channels, or even injected into the veins, it is rapidly eliminated by the expired air, and is consequently tolerated in relatively large doses.

It is a blood-poison, which, according to the studies of Hoppe-Seyler, Preyer, and Diakonow, reduces the hæmoglobin, depriving the red corpuscles of their oxygen. Roth and, later, Schönlein held that the sulphur combines with the iron of the red corpuscles in such a manner as to exist in the portal blood in the form of the sulphide of iron. This causes an increased formation and secretion of bile. Stifft, at Weilbach, has observed a diminution in the volume of the liver as the result of the treatment. According to the last writer, the black color of the protective garments which the patients wear is not due, as commonly asserted, to sulphide of iron, but to an increase in the excretion of bile.

Leichtenstern does not believe that the quantity of hydrogen sulphide absorbed by the patients from the water is sufficient to exert any toxic action on the blood. In the presence of oxygen, which is always in excess in the blood, the gas transforms itself into sulphurous acid. This view has been confirmed by Beissel, of Aix-la-Chapelle, and by Dronck, of Schinznach, who found sulphurous acid in the urine.

Kauffmann and Rosenthal attribute to the gas a toxic action on the blood, but think that in small doses the agent influences only the circulation and the respiration. Stifft is of the same opinion, and attributes to the hydrogen sulphide an action on the terminal filaments of the vagus, and, reflexly, on the centres of the circulation and the respiration.

The alkaline sulphur waters possess topical properties which may explain the modifications that are produced on mucous membranes and ulcerating wounds. They irritate the intestinal mucosa, and may provoke diarrhœa. After their ingestion they are eliminated either unchanged or oxidized into alkaline sulphates, which appear in the urine. No special physiological effect is attributable to them.

The action of the sulphur-baths is stimulant to the cutaneous nerves. They are distinguished from similar baths not containing sulphur by the fact that during their duration the patients inhale a small quantity of hydrogen sulphide gas.

Sulphur waters, as first noted by Bordeu, have exciting or stimulant properties. Numerous observations leave no doubt of this. Nowhere is thermal fever so common as at sulphur springs. Anginous attacks and nervous irritability are frequent accompaniments of the cure at such places. Bordeu has compared the action of the sulphur water to that of coffee. The phenomena of excitation are, however, transient and terminate in a state of sedation.

Formerly it was held that the sulphur waters caused an acceleration of the pulse simultaneously with a reduction of the temperature. Gerdy, Lambron, and Armieux, however, have noted a slowing of the pulse, whilst Grimaud, at Barèges, found an elevation of temperature at the time of the crisis, from the sixth to the twelfth day.

Cerebral activity is stimulated by the sulphur waters, even to the extent of causing insomnia.

The decomposed waters and those which become milky on exposure to the air exercise from the beginning a sedative effect, which renders them useful in special cases.

The elimination of sulphur by the respiratory passages and by the skin also explains some of the applications made of sulphur waters.

The calcium sulphide waters, being less alkaline, but richer in mineral principles, represent an attenuated form of sulphur waters, and are particularly valuable in irritative forms of disease.

The abundant escape of hydrogen sulphide from some springs renders possible inhalations of this gas, which has a special effect on the respiratory tract. At other springs the waters are employed principally on account of their temperature.

It is not the plan of this work to treat in detail of the therapeutic and clinical applications of mineral waters. These subjects are best considered in chapters dealing with the treatment of the individual diseases. We shall, however, give a brief outline of the diseases in general that are amenable to the form of treatment now under discussion.

The multitude of articles published on mineral waters have largely the appearance of prospectuses, and vaunt the particular water which they describe as a panacea capable of curing all forms of chronic disease. Yet clinical experience demonstrates incontestably that in certain conditions one water is more useful than another. Nothing would be of more service to the watering-places themselves than an unbiased investigation into the special uses of their waters.

Therapeutic Uses of Sulphur Waters. The sulphur waters are principally employed in chronic intoxications, as in syphilis, in rheumatism, in chronic inflammations of mucous membranes, in skin diseases, and in pulmonary tuberculosis. They are useful in chronic poisoning by the heavy metals, especially lead and mercury. The benefit derived from them has been attributed by some to an elimination of the lead in the form of a sulphur compound. Others, on account of the feeble mineralization of these waters, believe that they act rather by their general properties of stimulating the functions of the skin and the kidneys and by increasing internal oxidation, than by virtue of any medicinal ingredients.

Prompter and surer effects are obtained by magnesium and sodium sulphate waters, which transform the lead into a sulphate in the intestines and cause its elimination by the purgation which they provoke. Peyrou has studied the question experimentally and comes to the conclusion that sulphate of sodium is an antidote to lead and mercury.

According to Astrié, mercury forms in the tissues albuminates,

which are rendered soluble by the alkaline sulphates. The elimination of these compounds is favored by an active biliary secretion.

Güntz and others have noted at Aix-la-Chapelle that in cases of poisoning and in syphilitics mercury appears in the urine. Since Frascator, in 1546, prescribed sulphur baths in syphilis, the number of patients suffering from this disease is growing constantly at the resorts in the Pyrenees, especially at Luchon.

The sulphur waters have the property of calling forth latent specific lesions, especially upon the skin. Repeated hot-baths have an analogous action. *Syphilitic manifestations of the secondary period are aggravated by sulphur waters*, but the waters have been recommended in the tertiary syphilis, particularly by Lambron.

The treatment has two purposes or objects: On the one hand, it favors the rehabilitation of the health and the disappearance of the cachexia. On the other, it serves as a touch-stone, so to speak, by revealing latent traces of disease in cases where the malady is not well defined. It is to be remembered, however, that the sulphur waters have not antisyphilitic properties.

They frequently prove useful in cases in which it is desired to employ energetic mercurial medication, and for this reason it is customary at certain places to combine the mercurial treatment with the use of mineral waters. Large doses of the drug can then be made to pass through the system without danger of its accumulation. There is a class of syphilitic patients who are cachectic, not so much from the disease as from the abuse of mercury, and in these the use of sulphur waters is eminently beneficial. The stations best suited for syphilitic patients are Bagnères-de-Luchon, Aix-les-Bains, and Barèges. The last is preferable in cases in which there is a scrofulous taint.

These waters are also useful in chronic rheumatism, in atonic gout, in paralyses and other affections of the nervous system; but the question arises, Are the effects due to the hot-baths or the entrance of the sulphur into the system?

It is the fixed and deep forms of chronic rheumatism, those accompanied by a general impairment of health, that are especially influenced by stimulant waters and by energetic balneotherapy and hydrotherapy. The resorts recommended are Barèges, Luchon, Cauterets, and Aix-les-Bains. Fungous forms of arthritis do best at the first-named place. At Aix-les-Bains massage under a tepid

douche is practised, and proves valuable in many forms of chronic rheumatism and the slower varieties of gout.

Of skin disease the moist varieties, as weeping eczema, impetigo, and certain types of acne, are almost the only forms treated with sulphur waters. The influence of the latter appears in these cases to be quite complex. To the topical effect is added that of the elimination of sulphur by the skin, as well as the modification of the general health which the treatment is capable of bringing about.

In some instances, as held by Amsler, of Schinznach, it is not impossible that the sulphur exercises a parasiticide action. In the choice of a spring the period of evolution of the disease should be the guide. When the disease has a tendency to become acute the weaker sulphurous or the calcium sulphide waters should be selected, as Saint Gervais, Saint Honoré, Allevard, Enghien, and Moligt. Chronic and obstinate diseases are best treated by stimulating waters, as those of Luchon, Cauterets, and Barèges.

Sulphur waters are of special value in dealing with chronic inflammations of the mucous membranes of the nose, pharynx, larynx, trachea, and bronchi.

Under special conditions the sulphur waters produce a twofold action: the one local, topical; the other general. The development of this combined effect is favored by inhalations and spraying, which secure the passage of the medicinal agent directly to the diseased parts.

Patients suffering from chronic pharyngitis and laryngitis are sent to Cauterets, Eaux-Bonnes, Pierrefonds, or Enghien. Those with chronic bronchitis to Allevard, Eaux-Bonnes, Cauterets, Saint Honoré, Marlioz, Pierrefonds, Enghien, or Schinznach. Certain forms of gastritis and chronic enteritis are also benefited by sulphur waters, particularly those of Mahourat (Cauterets), of the Hontalade spring at Saint Sauveur, of Saint Honoré, and Saint Gervais. Uterine catarrhs are successfully treated at Saint Sauveur, Eaux-Chaudes, Enghien, and Saint Honoré, while vesical catarrh is improved by the waters of Olette and la Preste, and also those of Enghien.

The discovery of the tubercle bacillus attracted attention to the possible value of the inhalation treatment as a means of acting directly upon the diseased foci. Physicians at sulphur springs strongly urged the use of hydrogen sulphide as an anti-bacillary agent, but the expectations which their writings aroused were not fulfilled.

The sulphur treatment may be of some value in tuberculosis, but its application is quite difficult.

Phthisical patients, especially those presenting the slow, inactive form of the disease, are sent to Eaux-Bonnes. As hæmoptysis sometimes develops during the treatment at Eaux-Bonnes, "the cure" should not be prescribed for irritative types of the disease nor in cases subject to hæmoptysis. Cauterets, Allevard, and Schinznach are recommended in the slow form of phthisis, in which the lesions are limited in extent. Amélie-les-Bains, le Vernet, and Gréoulx should also be mentioned in this connection.

The sulphur waters are very useful in scrofulous conditions. At Barèges good results have also been achieved in the articular and osseous forms of tuberculosis. This is also true of the springs at Eaux-Chaudes, Challes, and Schinznach.

Finally, the sulphur waters also have a favorable influence upon indolent varicose ulcers, fistulous tracts, old traumatic lesions, such as luxations, fractures, and gunshot-wounds. Barèges is the station of choice for these conditions.

Saline Waters. Various authors have grouped the saline springs in one class. These waters undoubtedly present a certain number of common characteristics. They are quite strongly mineralized, and contain a sodium salt which is not decomposed in the economy, and the elimination of which is carried out by several emunctories, chiefly by the kidneys. (Liebig, Wöhler, Dumas.)

By reason of their saline constitution, these waters in their passage through the digestive tract provoke a number of phenomena that may be attributed, in a large measure, to a modification of osmotic conditions. The authors in question are agreed that this great group of saline waters may be subdivided into two classes—the chlorides and the sulphates. We shall follow the example of Durand-Fardel, who makes the sodium-chloride waters a large family, which appears to us natural.

Sodium Chloride Springs. The sodium chlorides come from the secondary strata which enclose deposits of rock-salt, of gypsum, and of variegated sandstone. When they are charged with carbonic dioxide they are generally derived from more or less recent volcanic strata, viz., the basalt and lava rocks.

The temperature of these waters differs. The cold springs are richer than the warm in carbonic dioxide. Their composition presents a large number of variations, which it is impossible to group

under one head, but they are all characterized by the predominance of sodium chloride. The other principles which are present are the sulphates, carbonates, sometimes sulphides, iodides, bromides, and iron. Of gases we find frequently a considerable quantity of carbonic dioxide and a small proportion of hydrogen sulphide or of nitrogen. In certain countries, notably in Germany, the action of the bath is re-enforced by the addition of mother-liquids which remain after the evaporation of the saline waters in the preparation of salt for commerce. These residues contain a considerable quantity of soluble principles from which sodium chloride separates itself in crystallizing. The sodium chloride waters are very numerous and of a variable constitution. Durand-Fardel has established and described the following classes, the chloro-sulphides, the chloro-bicarbonates, and the chloro-sulphates.

The division which we shall adopt is as follows:

Class 1, the pure chloride of sodium waters; class 2, the mixed sodium chloride, comprising the chloro-sulphides and the chloro-bicarbonates.

The pure chlorides, the only ones with which we shall at present deal, are either cold or warm; generally clear, transparent, of a salty taste, and produce upon the palate a sensation of heat. Those that are charged with carbonic dioxide have a very agreeable taste and are preferable for internal use. The proportion of sodium chloride which they contain is very variable; it oscillates between 1 and 25 per cent.; some of the richer ones are concentrated before use by evaporation. Le Bret divides them into the gaseous and the non-gaseous chlorides. This is of some importance, but the medicinal properties of the waters seem to us to be controlled by their relative richness in sodium chloride. We believe it is best to distinguish the weak and strong sodium chloride waters (Soolen of the Germans). The first—that is, the weak—are employed chiefly internally; the others externally. In Germany it is customary to consider those waters as weak that contain less than 10 parts of sodium chloride in a 1000; as strong, those containing more than 15 parts in a 1000.

FEEBLE CHLORIDE OF SODIUM WATERS (1 to 1000).

Stations.	CO_2.	NaCl.	Total.	Temp.
	c.c.			
Bourbon-l'Archambault	......	2.40	4.35	52° C.
Bourbonne-les-Bains	......	5.80	7.60	58
Balaruc	......	6.80	9.10	48
Lamotte	......	3.80	7.40	59
Bourbon-Lancy	......	1.30	1.80	46–56
Creuznach (Elisenquelle)	......	9.40	11.70	
Baden-Baden (Hauptquelle)	......	2.10	2.80	68
Niederbronn, Alsace	......	3.00	4.60	
Soden, Nassau (Warmbrun)	1015	3.40	4.70	23
Kissingen (Rakoczy)	1305	5.80	8.50	
Wiesbaden, Nassau (Faulbrunn) . . .	......	3.40	4.30	13
" " (Kochbrunn) . . .	200	6.80	8.20	68
Homburg (Elisabethenbrunn) . . .	1039	9.80	13.20	
Pyrmont (Salzquelle)	734	7.00	10.70	
Kronthal	1258	3.30	4.50	

STRONG CHLORIDE OF SODIUM WATERS (MORE THAN 1 TO 1000).

Stations.	CO_2.	NaCl.	Total.	Temp.
Salies-de-Béarn	......	245.000	......	15° C.
Salins (Jura)	......	22.740	......	10.5
Salins-Moutiers	12.48	11.317	......	38
Rheinfelden (Argovie)	......	311.630	318.8	10
Bex (Vaud)	......	156.660	170.2	15
Salzungen, Prussia	......	256.600	265.0	12
Frankenhausen, Prussia	......	249.600	259.3	18
Hall, Austria, Tyrol	......	255.500	263.9	12
Ischl, Austria	......	236.100	245.4	15
Gaseous.				
Nauheim (Taunus) (Kurbrunnen) . . .	......	15.400	18.7	21
Soden (Taunus) (Soolsprudel	756	14.500	16.8	30.5
Nauheim (Hesse) (Friedrich-Wilhem-Sprudel)	578	29.300	37.1	35
Rehme-Oeynhausen (Prussia) . . .	753	24.850	......	27–31

It is important to distinguish among the saline waters the warm and the cold, the gaseous and the non-gaseous. Yet it is difficult to classify the various springs according to these distinctions; for we frequently find in the same place cold springs and warm springs, gaseous and non-gaseous waters. The presence of iodides and bromides in these waters should also be taken into consideration. It is especially the mother-liquors which are added to the baths that contain these principles in largest proportion.

Among the sodium chloride and iodide waters we shall cite Kreuznach, in Prussia (0.08 of iodide of magnesium); Hall, in Austria (0.058 of iodide of magnesium); Wildegg, in Switzerland (0.027 iodide of sodium); Heilbrun, in Bavaria (4.95 sodium chloride, 0.028 sodium iodide, 0.41 sodium bromide). The mother-liquors contain chloride of sodium and calcium, rarely of magnesium. When they are obtained from iodide and bromide waters they are naturally rich in compounds of iodine and bromine.

The principal bromine waters are: Salies-de-Béarn, 1.050 bromide of potassium; Creuznach, 0.625 bromide of magnesium; Bourbonne-les-Bains, 0.005 bromide of sodium; Balaruc, 0.032 bromide of magnesium; Salins, 0.031 bromide of magnesium; Wildegg, 0.030 bromide of sodium; Heilbrunn, 0.410 bromide of sodium.

The mother-liquors of Hall contain nearly a 1000 grammes of saline matters, of which 945 are sodium chloride, 2 magnesium iodide, and 3.2 magnesium bromide.

Those of Kreuznach contain 256.8 grammes of sodium chloride, 0.077 of potassium iodide, 6.814 of potassium bromide.

Therapeutic Effects of Saline Waters. The effects of the chloride waters taken in the form of a beverage are similar to those of sodium chloride. Let us dwell for a moment upon the chief properties of this body, and first of all upon the part which it plays in the formation of the juices and protoplasm of the body. We take into our system on an averge 20 grammes per day, 4 to 5 grammes of which are again found in a litre of urine. During the treatment at salt springs the consumption rises to 35 grammes in the 24 hours. What effect does this quantity produce? The ingestion upon an empty stomach of moderate amounts of salines, especially when this water is rich in carbonic dioxide, develops in the mouth an agreeable sensation of freshness or warmth, while at the same time the salivary secretion is stimulated. In the stomach saline solutions produce unquestionably powerful effects. Moderate doses excite the secretion of the gastric juice, augment the total acidity, and further the formation of peptones. For these reasons they are capable under certain conditions of improving the digestion. But when the stomach is diseased or irritable they are apt to lead to acid hyperpepsia (hyperpepsia chlorhydrique). The internal use of these waters, then, should always be regulated by the state of the gastric mucous membrane. It has been asserted that sodium chloride stimulates the movements of the stomach. This may be possible in the physiological state, although it has not been fully demonstrated. In cases of hyperpepsia the use of salt has for its commonest effect a retardation of the evacuation of the stomach, and therefore aggravates the dilatation, which is the consequence of such a disturbance. When large doses of salt-water are employed the sodium chloride passes into the intestines in sufficient quantity to set up a purgative action, both by virtue of an increased peristalsis and of changes in the intestinal osmosis. It is very probable that the effects produced

are not the same when the dose of salt is represented by a large quantity of a feebly salt solution as when a relatively small amount of a concentrated solution is ingested. The strong solution exercises a more powerful influence upon the phenomena of osmosis. The purgative effect produced by the use of mineral waters is sometimes facilitated by the presence of a small quantity of sodium sulphate or magnesium sulphate. The sodium chloride stimulates not only the secretions of the digestive tract proper, but also those of the liver and the pancreas.

This whole question of the influence of saline solutions upon the functions of the gastro-intestinal tract and its tributary organs deserves to be studied diligently by the aid of modern methods of analysis. The researches of Barral, Kaupp, Voit, and Feder have established that salt is eliminated principally by the urine, and that this elimination to be complete requires several days. It is accomplished by an alkalinization of the urine (Salkowski). By facilitating the diffusion of fluids, the salines, when in excess, lead indirectly to an increased disassimilation of albuminoids.

Bischoff, Voit, Kaupp, and others attribute to sodium chloride the ability to increase the nitrogenous excretion; and according to Dehn potassium chloride has a similar action.

The small amounts of iodide and bromide contained in some of the waters do not seem to exert any physiological action.

The Effects of the Baths in Saline Waters. The external procedures, particularly the baths, play a very important *rôle* in the therapeutic use of sodium chloride. The baths generally contain from 2 to 3 per cent. of sodium chloride, *i.e.*, approximately, 12 to 18 pounds of salt to 300 litres of water. Sometimes the quantity of salt is 8 to 10 per cent.; in other cases only 1.5 per cent.

The saline baths give rise to phenomena of stimulation, such as are produced by baths of mineral water in general. The skin at first became pale, then red, and after several hours reassumes its normal color. The bath, therefore, influences the distribution of the blood and undoubtedly provokes reflex phenomena that may have a certain therapeutic value. The most important physiological effects are those bearing upon nutrition. Röhrig, Zuntz, and Paalzow have studied the question from the standpoint of the respiratory variations. They have found that a bath containing 3 per cent. of salt increases the absorption of oxygen and the exhalation of carbonic

dioxide, the increase being 15.3 per cent. in the case of the former; 25 per cent. in that of the latter. These phenomena are not observed with baths of soft water, and are prevented in experiments on animals by curarization. Beneke has also observed an increase in the excretion of nitrogen. The study of this question has recently been resumed by several experimenters, especially by Keller and Gauly. Keller, of Rheinfelden, has compared the effects of the simple bath with those in water containing 3 per cent. of sodium chloride. The results which he has obtained may be tabulated, as follows:

	SALT-BATHS.	SIMPLE BATHS.
Quantity of urine	Increased.	Diminished.
Chlorides	Increased.	Diminished.
Phosphates	Increased.	Diminished.
Nitrogen	Diminished.	Increased.
Sulphuric acid	Increased.	Increased
Body-weight	Diminished.	Increased.

The saline baths, contrary to that which was formerly believed, diminished, according to Keller's table, the excretion of nitrogen, while the simple baths slightly increased it. The salt-baths augment the non-nitrogenous excretion. Gauly, in his experiments, in which he followed the method of Robin, arrived at different conclusions; but he made use of water richer in salt. The waters were of the following strength: 6 per cent., 12 per cent., and 25 per cent. of salt. These are the principal results he obtained. The bath of 6 per cent. salt water produced a diminution in the quantity of urine and in the organic components, uric acid and nitrogenous extractives. It had no influence upon the total solids and upon incompletely oxidized nitrogen. It increased the inorganic substances, the total nitrogen, the urea, the coefficient of nitrogen oxidation, the chlorides, phosphoric acid, and the ratio of phosphoric acid to the total nitrogen. The bath in 12 per cent. salt solution augmented all the elements of the urine, but diminished the ratio of phosphoric acid to the total nitrogen. Finally, the 25 per cent. bath caused a diminution in the incompletely oxidized nitrogen, in the nitrogenous extractives, in the uric acid, and in the ratio of phosphoric acid to the total nitrogen. It increased the other elements. After the cessation of the bath, the incompletely oxidized nitrogen and the nitrogenous extractive matters, as well as the ratio of the phosphoric acid to the total nitrogen, remained below normal, while the increase in the other elements became more marked. These experiments establish the fact

that the effects of the baths vary markedly with the relative richness of the water in salt; but they do not invalidate the conclusions of Keller. Moreover, in spite of the care taken by the author, they are not conclusive.

In some instances from 1 to 20 litres of mother-liquor are added to the bath-water. The effects of this method are not fully determined. The same is true of the physiological action of such douches.

We may conclude from the facts here stated that the sodium chloride treatment is stimulative and recuperative. By increasing the combustion of the non-nitrogenous elements it facilitates the removal of an excess of fat. It produces also a general tonic action, increases the appetite, and improves digestion; it favors the reconstruction of nitrogenous tissue, although there are recorded results which point to a decreased assimilation.

Sea-water. The sea is in some respects an immense reservoir of mineral water. It is the natural type of the sodium chloride waters. Its chemical composition is very complex, for it contains no less than 30 elements; but of these sodium chloride represents three-fourths by weight. Its richness in salt depends upon the latitude. It diminishes in a fairly regular proportion toward the north, as the following table will indicate:

SODIUM CHLORIDE IN A THOUSAND PARTS.

Red Sea	42
Mediterranean	40
Atlantic Ocean	38
Channel	36
North Sea	33
The Sound and Cattégat	16
The Western Baltic	8
The Eastern Baltic	4.33
The Bay of Kronstadt	0.61

Along the coasts the proportion of salt varies according to the absence or proximity of water-courses. The other saline elements differ markedly in different bodies of water. The most important among them is the sulphate of magnesium. More of this salt is found in the Mediterranean than in the Channel. Sea-water contains, in addition, a peculiar fatty organic substance, designated mucosin, and variable amounts of gas. The density of sea-water is from 1025 to 1032; this increases from the poles to the equator.

The mean temperature of sea-water during the summer, from the 21st of June to the 22d of September, is noted in the following table:

In the Mediterranean	72° to 82° F.
In the Atlantic Ocean	72 " 74
In the North Sea	62 " 64
In the Baltic	60 " 67

In the Mediterranean the temperature suitable for bathing is reached in June and persists until November.

In the treatment of diseases by sea-baths three principal factors are involved—the air, the water, and the beach. The water is employed, as in the case of other mineral waters, in the form of beverage, bath, and douche. The internal use of sea-water dates back to antiquity, for Pliny gives a prescription for sea-water.

The systematic therapeutic employment of sea-water is sometimes attributed to Richard Russell (1750).

From the numerous treatises on the subject we may infer that sea-water belongs to the class of strong chloride waters.

In the dose of two or three glasses it has in the adult a purgative effect. In order to complete the marine cure some physicians are in the habit of letting their patients drink a small quantity of sea-water; but the use of this water under such conditions is in no wise comparable to that of the sodium chloride mineral waters, as generally used.

The experiments of Lisle with bread made with sea-water have not been followed up.

External Treatment with Sea Water. The external treatment is the most important. It comprises the baths in cold sea-water given in establishments, moderate hydrotherapy, and, finally, the sand-baths. During the treatment the patients are subjected to the action of the sea-air, which exercises an appreciable influence upon the organism, an influence which has in a measure been reproduced at those resorts where the patients respire in a salt-laden atmosphere.

The factors of which it is necessary to take account in considering "God's vast pond," to employ an expression of Michalet, are the density, the pressure, and the chemical composition of the water and the mechanical action of the waves. The physiological effects produced are very analogous to those determined by cold baths, but are more intense. They are difficult to analyze, because the patients,

when in the bath, respire the sea air and sometimes also swallow a little sea-water. The sea-baths should be taken at least three hours after meals. It is best to choose the period of high tide; the beach is then warm and the waves are strong. In the resorts of the North the water and the air are never too warm, but they may become too cold. The patient should enter the water rapidly and practise energetic movements while in the bath, and it is preferable to seek the waves. The first feeling is one of slight chilliness, which soon vanishes; but sometimes a second chill is experienced about five or ten minutes after entering the bath. It should be avoided, if possible, and is the sign for leaving the water. After the bath the patient should take light exercise on the beach. Those who are subject to headache after the bath can prevent it by taking a hot pediluvium on leaving the water. Only one bath should be taken in the day; and after a series of fifteen or twenty an intermission of a few days is advisable. Forty to fifty baths comprise the season. The cold sea-baths are not well borne by feeble and anæmic individuals. It is best to have recourse in such cases to bathing in a bath-room, the sea-water being heated. This is a method which imitates the baths taken at the watering-places. At some resorts it is customary to make use of the douche, the effects of which have been especially studied by Lemarchand. The simple cold douche, or the Scotch douche may be used, too; rarely the tepid douche. (See Thermic Agents.) The duration should be less than that of the douche with ordinary water.

Sand-baths. At certain places it is customary to give sand-baths. For this purpose a trench is dug on the beach and then, after the sun has heated the sand, the child (for it is in children that these baths are particularly useful) is placed in it and protected by a tent of white flannel. The duration of the sand-bath is from twenty minutes to a half-hour. In Southern resorts it may be prolonged up to an hour.

Seaside Resorts. We have cited the winter maritime stations which are frequented for climatic treatment. There remain yet to be mentioned the principal summer resorts which are suitable for the maritime treatment. There is a large number of winter stations that are well adapted, and the treatment can there be prolonged until the autumn. The watering-places of the northern European coast can be passed over in silence; they are of little interest. We shall merely name a few, such as Scheveningen, in Holland; Ostend, in Belgium; the resorts of Great Britain, such as Dundee, Leith, Dunbar, in Scot-

land; Newcastle, Whitby, Hull, and Yarmouth, on the eastern and southern bank of the Thames; Ramsgate, Folkstone, Hastings, Brighton, the Isle of Wight, Weymouth, Dartmouth, and Plymouth, on the western coast; Bristol, Cardiff, the suburbs of Liverpool, the banks of the Clyde; and in Ireland, Belfast, Dublin, and Cork. To these resorts should be added those we have named when speaking of climatic stations of Great Britain. The resorts of northern France, while possessing the same advantages as those of the coast of England, are less warm and the temperature is less equable. They are, however, popular among the Parisians, who prefer them on account of their freshness and proximity to Paris. We should mention Berck-sur-Mer, an interesting place by reason of the hospital which receives the little children coming from the hospitals of Paris, Boulogne, Treport, Dieppe, Trouville, Deauville, St. Malo, and other resorts. On the western coast we find Le Croisic and Pornic. In the Bay of Gironde, Royan and Arcachon. Toward the south, are Bayonne, Biarritz, and Saint Jean de Luz. The principal resorts of the South which have not yet been mentioned are Marseilles, Fréjus, Porto Maurizio, Cogolito, Genoa, Sestri-Levante, Pegli, Spezzia, Viareggio, Livourne, Bocca d'Arno, Civita Vecchia, Naples, and Castellamare. On the Adriatic Coast we find Ortona, Pesaro, Fano, Sinegaglia, Rimini, Venice, etc.

The Therapeutic Uses of Sodium Chloride Waters. The sodium chloride waters are useful in the treatment of scrofula and local tuberculosis, in certain forms of digestive disturbances, in diseases of the genito-urinary organs, and in the paralytic affections of the nervous system, in chronic rheumatism, etc. Their best use is found in scrofula, in which their effects are remarkable in children and in adolescents possessing a predisposition, inherited or acquired, to tuberculosis. Naturally, it is the visible manifestations, those which are properly called scrofulous, that are most readily influenced. The articular and osseous lesions due to tuberculosis are more resistant; but even in these conditions amelioration and occasionally cure is obtained. Clinical experience has shown that in these cases the external treatment is more important than the internal. For this reason the preference should be given to the strong sodium chloride waters and to stations at which the balneologic features are good. Those resorts where the mother-liquors are utilized, particularly when the atmosphere is also impregnated with sea-salt are especially appropriate to this class of cases.

The treatment is very valuable in the severe forms of scrofula, when fever and the acute symptoms have subsided. Life in the open air and inhalation of the sea-air are important adjuncts to the treatment. The treatment is efficacious only when sufficiently prolonged.

Where we have to deal with tuberculosis of the bones and of the articulations, the patient should remain permanently on the sea-coast, or at least until the treatment has given such results as we expect.

The benefits which have been obtained from the treatment at Berck, and which have been published in the report of Bergeron, are really remarkable. During a period when the patients were not selected, 280 out of 380 cases were cured; that is, 74 per cent. Since that time Cazin and Perrochaud have shown that even in suppurative coxalgia good results may be achieved at Berck, although this station is far from having the most advantageous conditions. The climate is cold, the place is very sandy, and the atmosphere dusty.

The Italians have established along the coast of their country a number of hospitals, which have rendered great service.

The watering-places best adapted to the treatment of scrofula are: in France, Salins, in the Jura; Salies, near Moutiers; Salies-de-Béarn (Basses-Pyrenees), Bourbonne, Balaruc, Lamotte-les-Bains; in Germany Kreutznach, Manheim, and Rheinfelden, and Bex-Lavey in Switzerland, and Ischl in Austria. At Salies the waters contains 27 grammes of sodium chloride per litre; sometimes a small proportion of the mother-liquor is also added to the water. Both the external and the internal treatment are employed at Salies, and good results are obtained in all the manifestations of scrofula. The waters of Salies are particularly useful in the osseous forms of tuberculosis. An establishment exists at Biarritz for the use of sodium chloride waters. The other resorts are appropriate only for the superficial and glandular forms of tuberculosis.

In diseases of the digestive tract the sodium chloride waters are employed, especially in the form of beverages. On this account the waters easy of absorption are always chosen—that is, those containing a small or moderate amount of the salt. The particular affections of the digestive tract amenable to the treatment have not been fully determined. They are those commonly classed as atonic forms of dyspepsia, both gastric and gastro-intestinal. But this is a vague term. Among the diseases of the stomach the subacute catarrhal gastritis and the chronic gastritis, with more or less advanced gland-

ular torpidity, especially when accompanied by constipation, are distinctly benefited by the treatment. Of the affections of the large intestine, constipation, and particularly the condition known as "abdominal plethora," are improved by the sodium chloride waters. But it is important in constipated persons, whether obese or not, to take into account the state of the stomach before prescribing saline waters. Hyperpeptic gastritis should always be considered a contraindication to their employment. The principal resorts suitable for the treatment of gastro-intestinal maladies are Kissengen in Bavaria, Niederbronn in Alsace, and Bourbon l'Archambault. The Kissengen waters contain from 2 to 5 grammes of salt. They are also quite rich in gases and are somewhat ferruginous. The patients frequenting Kissengen are subjected to a rigid dietetic regimen for the treatment of obesity. The waters of Niederbronn, where the reducing treatment is also in vogue, contain 3 grammes of sodium chloride per litre. They are well borne, and the dose can be progressively increased until 8 or 10 glasses are taken in the day. The water is particularly useful in chronic constipation. At Bourbon l'Archambault, the waters of which contain 2.2 grammes of sodium chloride per litre, good results are obtained in gastro-intestinal atony. The sodium chloride waters are also beneficial in some of the diseases of the female sex, especially in the uterine catarrhs of scrofulous persons. They have also been employed in metritis and endometritis when acute exacerbations are no longer to be feared. They are contraindicated by the existence of an irritability of the nervous system and the presence of pain. Kreuznach, Salies-de-Béarn, and Bourbon l'Archambault are the preferable resorts. In some instances it is advisable to resort to warm sea-baths in bath-rooms, or even to cold sea-bathing.

Kreuznach and Salies have a favorable, but as yet unexplained influence upon uterine fibromata, whether accompanied by metrorrhagia or not. A number of instances of the expulsion and of the atrophy of such tumors are recorded. In any case the hemorrhages are either entirely arrested or distinctly lessened.

Several of the sodium chloride waters enjoy a great reputation in the treatment of paralysis, especially those forms which have their origin in a cerebral apoplexy. Some writers have claimed that they are useful soon after the onset of paralysis, but undoubtedly they have mistaken the spontaneous amelioration for a therapeutic effect. When their use is postponed, as it should be, until the period of cicatriza-

tion, the waters probably act by producing a derivative influence upon the digestive tract by reason of their laxative effects, and also by a reflex action, of which the cutaneous stimulation is the point of importance. The patients at these stations are subjected both to the internal and external treatment, sometimes to the latter alone. At Balaruc the douche plays an important part. Bourbon l'Archambault, Bourbonne, and Wiesbaden are useful in this class of cases. Some of the so-called functional paralyses, which are probably due to peripheral neuritis, have been treated successfully at Wiesbaden.

All the various manifestations of chronic rheumatism are amenable to the treatment by saline waters. Bourbon l'Archambault, Bourbonne, Wiesbaden, Lamotte, and Salies can be recommended in these affections. Other indications for the use of sodium chloride waters are traumatic lesions, such as fractures and malarial intoxication.

Bourbonne, it appears, hastens the consolidation of fractures.

The contraindications of sodium chloride have not been definitely established. Chlorosis, the scorbutic affections, and organic diseases of the heart and great vessels, and pulmonary tuberculosis are those generally named. The action of these waters in chlorosis depends naturally upon the condition giving rise to this disease. In true chlorosis, in which the existence of hyperpepsia is frequent, the employment of these waters, especially for internal use, is contraindicated. To prove that these waters are useful in scorbutus, we have the interesting fact that after the Crimean campaign a large number of the patients suffering from this disease were cured at Balaruc. It seems very probable, however, that the old practitioners designated by the term scorbutic affections different forms of purpura, a condition which contraindicates the employment of sodium chloride waters. According to Rotureau, the sodium chloride waters provoke hæmoptysis, accelerate the breaking-down of tuberculous granulations, and impress upon the disease a more rapid course. It will subsequently be shown that tuberculous patients bear well certain mixed chloride waters.

Bicarbonate of Soda Waters. Sodium bicarbonate produces such marked and peculiar effects upon the digestive tract and upon general nutrition that the waters which contain it in sufficient proportion to produce medicinal effects should be considered separately and placed in a distinct group by themselves. These waters are saturated with carbonic dioxide, and for this reason are termed by some writers alkaline gaseous waters. They are either cold or warm, and their

chemical composition is commonly very complex. Besides sodium bicarbonate other carbonates are found, such as the carbonate of iron; also sodium sulphate, sodium chloride, sodium phosphate, lithium, and arsenic. France possesses the most noted resorts that belong to this group. The bicarbonate waters are divided into the strong and the weak. The most important of the French resorts of this class is Vichy, situated in the central part of France, in a district remarkably rich in bicarbonate of sodium springs. Most renowned among the strong waters are the Hôpital, Grand-Grille, and Celestins, at Vichy; the Marquise, at Vals; the Souveraine and Clementine, at Le Boulou; the Pauline, at Vals; Andabre; while La Chapelle (Châteauneuf) belong to the weaker springs. Rohitsch (Ignatzbrunnen), in Styria; Bilin, in Bohemia; and Passug (Ulricusquelle), in Switzerland, belong to the strong waters. Fachingen and Apollinaris, in Prussia; Obersalzbrunn, in Silesia; and Soulzmatt, in Alsace, are weaker.

SODIUM BICARBONATE WATERS.

Stations.	Springs.	Bicarbonate of sodium.	Chloride of sodium.	Sulphate of sodium.	CO_2.	Temp.
Strong:						
Vichy	Hôpital,	5.029	0.518	0.291	1.067	31.7°C.
	Grande-Grille,	4.883	0.534	0.291	0.908	42.5
	Célestins	4.101	0.550	0.314	1.299	15.2
Vals	Marquise,	7.100	0.060	0.950	2.600	13
Le Boulou	Souveraine,	6.500	0.330	0.260	2.200	13
	Clémentine,	6.470	...	...	...	17
					c.c.	
Rohitsch (Styria)	Ignazbrunnen,	8.600	0.300	...	0.348	13
Passug (Switzerland	Ulricusquelle,	5.300	0.800	...	0.954	8
Bilin (Bohemia)	....	4.200	0.300	0.800	1.337	12
Feeble:						
Vals	Pauline,	1.010	0.040	0.150	2.138	15
Andabre	....	1.820	0.090	0.010	1.138	10
Châteauneuf	La Chapelle,	2.080	0.430	0.140	1.650	17
Fachingen (Prussia)	....	3.600	0.600	...	0.945	10
Obersalzbrunn (Silesia)	....	2.400	0.100	0.400	0.630	7
Apollinaris (Prussia)	....	1.200	0.400	0.300	1.500	21
Soulzmatt (Alsace)	....	0.900	0.100	...	0.972	10

All of these waters contain iron, particularly those of Mesdames, Lardy, and Hauterive. Besides Vichy, Cusset is noted for its cold and especially for its ferruginous waters, which have a variable richness of sodium bicarbonate, ranging from 2.35 grammes to 5.2 grammes. A large number of the waters of the district of Vichy are used only for exportation. Some of these are even richer in sodium bicarbonate than that of Vichy itself, as, for instance, that of the Vesse, which contains 6 grammes, and that of Saint Yorre, which contains 7½ grammes. Vals is also the centre of a region

having an abundance of waters of this kind, which emerge here from granitic strata. The waters of Vals have a more varied composition than those of Vichy. They, indeed, form a sort of scale of mineralization. They are almost too variable and too numerous. Exploited by zealous proprietors, they do not present that fixity of constitution and of name, without which scientific study is impossible. While some of the springs contain as much as 9 grammes of bicarbonate, others are almost entirely gaseous. La Dominique is distinguished from all others. In it Henry found, in 1859, 1.3 grammes of free sulphuric acid. No analysis has been made since his time.

The weaker French waters are almost solely used for exportation. Among them may be mentioned Sail-sous-Couzan (Loire), Saint Romain-le-Puy (Loire), Marcols (Ardèche), Neyrax (Ardèche), and Saint Sauveur de Montagut (Ardèche).

PHYSIOLOGIC EFFECTS OF SODIUM BICARBONATE WATERS. The sodium bicarbonate waters constitute a powerful medicament, the effects of which may be not only profound but also remarkably lasting. The bicarbonate of sodium certainly plays an important *rôle* in this connection. But there exists a very appreciable difference between the action of sodium bicarbonate taken in the pure state and that of the stronger bicarbonate waters, a difference which cannot be clearly explained. A similar difference is exemplified by other mineral waters. We believe that the greater efficacy of sodium bicarbonate waters, notably of those of Vichy, when taken at their source, depends on the one hand upon the complex composition of the waters which facilitates absorption, and on the other upon the temperature which acts in the same direction, and, moreover, furthers the action of the water upon the liver. It is necessary, in addition, to take into consideration the mode of administration of the waters and the peculiar conditions under which the patients live at these resorts during the treatment. In this respect much improvement could be made at Vichy, where the patients are too much abandoned to themselves and condemned to the barbarous *régime* of *table d'hôte*. The bicarbonate waters exercise their effects especially upon the digestive tract and its neighboring glands and upon general nutrition. They increase the buccal secretion and tend to augment that of the stomach. In a large number of cases, when taken upon an empty stomach, they meet in the latter organ acid products, the residue of the preceding meal; and the bicarbonate is then transformed, in part or entirely, into

chloride of sodium, whilst the carbonic dioxide is disengaged and produces a peculiar tickling sensation in the nose. It is generally admitted that the decomposition of the sodium bicarbonate takes place even in an empty stomach. The alkalies are capable of stimulating the secretion of the gastric juice, the acid of which subsequently attacks the bicarbonate salt. The question has not, however, been fully settled, though this process, however, explains the rapid alkalinization of the urine, which has been ascribed to the abstraction of hydrochloric acid which has been supposed to be contained in the blood. The studies pursued by the writer and Winter show that the blood furnishes directly only sodium chloride. The phenomena which follow the ingestion of bicarbonate waters depend upon complex conditions even in the physiological state. They vary especially according to the relation which the time of taking the waters bears to that at which the meals are taken. When glandular atrophy of the stomach-walls exists, sodium bicarbonate remains almost unchanged in the stomach, and the alkalinization of the digestive tract and of the blood is rapidly produced. In other affections, although a part of the bircarbonate may be decomposed in the stomach a part passes on into the intestine.

Extended studies have shown that the principal effect of alkaline medication is to shorten the process of gastric digestion. But it is not possible to obtain a precise conception of the medicinal effects in disease unless the disturbances in the progress of digestion, of which the writer gave the first description, are taken into account.

The administration of sodium bicarbonate at a considerable distance from the meal, and the same no doubt holds good of mineral waters, has for its principal effect the shortening of gastric digestion. In patients subjected to this treatment analysis shows, even when large doses are employed, that gastric digestion is stimulated. But this is only apparent, although experimenters like Linossier have been misled, as they have not taken into account the modification in the evolution of the digestive processes. The supposed excitation is due to the fact that, the gastric changes proceeding more rapidly, the maximum of chemical changes is reached sooner. In reality the employment of sodium bicarbonate always decreases the secretion of acid and tends to depression of the stomachic functions—if not always during the treatment, at least subsequently. If given several hours after meals, it saturates the gastric contents, cuts short digestion, and excites the evacuation of the stomach.

It is consequently the remedy *par excellence* in that pathological condition to which we have given the name dilatation.

Alkaline waters exert an influence upon the pancreatic and hepatic secretions, either reflexly or indirectly, after the carbonate has entered the blood and has increased the alkalinity of this fluid of the body.

Regarding the influence of the alkalies in the nutritive processes, results so far obtained are not concordant. Although we have as yet no precise physiological facts, it is certain that the alkaline treatment produces, in addition to a decrease in the acidity of the urine, a diminution in the nitrogenous excretion (urea and total nitrogen), and frequently also in that of the phosphoric acid.

These effects, which persist for a greater or less period after the treatment, appear to result from the alkalinization of the body-fluids and the consequent changes in cellular protoplasm. Whatever the explanation, the fact is undeniable—there is an inhibitory action on the digestion of the albuminoids. It should be added, however, that in certain patients who are not cancerous and have an abnormally low nitrogen excretion, small doses of sodium bicarbonate or of alkaline mineral waters may, by stimulating appetite and digestion, determine an increase, at least temporarily, of the nitrogenous elimination.

The alkaline treatment possibly favors the combustion of the hydrocarbons, judging from the results obtained in diabetes and obesity. Many of these facts, however, merit closer study.

An important question is, can an excess of sodium in the blood and body-fluids produce an organic disintegration, a diminution in the plasticity of the blood, anæmia and œdema; in a word, the state designated by Trousseau as "alkaline cachexia?" The physicians at various watering-places, notably at Vichy, have vigorously combated this opinion, and have attempted to show that the sodium bicarbonate waters are reconstructive and even favorable to the hæmatopoietic processes, but the views of Trousseau nevertheless contain a measure of truth.

It should be noted in the first place that at the period this opinion was advanced the treatment at Vichy was vigorous and the doses frequently excessive. The alarm sounded by Trousseau contributed greatly to the reform of the internal treatment. In the second place, the opinion of Trousseau applies to a certain number of cases, but not to all. For, if it is true, as it undoubtedly is, that in some cases the moderate use of Vichy water has a reconstructive influence, it is

nevertheless true that in other cases the waters, even in moderate doses, are harmful and absolutely contraindicated in a large number of patients, who are, nevertheless, sent to Vichy or a similar resort. In Trousseau's time, when the patients drank large quantities of water, they returned from the watering-places in a lamentable condition. We have witnessed such effects, which might have been avoided had proper attention been paid to the condition of the digestive tract and to the state of general nutrition. These waters are not to be prescribed without these precautions.

Of the effects produced by the waters taken internally, a part is ascribed to the carbonic dioxide, and consists in a mild degree of intoxication and in an increased activity of the circulation. The later effect is sedative.

The bath is soothing and agreeable; it facilitates the treatment when it is desirable to stimulate the skin functions and to exert a sedative effect on the nervous system.

Therapeutic Uses. The sodium bicarbonate waters are used in a considerable number of morbid states, such as diseases of the stomach, the liver, the mucous membranes, rheumatism, gout, diabetes, albuminuria, obesity, and certain cachectic states. Patients suffering from functional dyspepsia are nearly always sent to such waters, a practice that is not always good. However, all forms of chronic gastritis may be benefited to a certain extent by the alkaline waters if a correct choice of the kind of water suited to the stomach is made and a proper mode of administration carried out.

Unfortunately, nearly all patients, whatever their form of disease, are subjected to the same mode of treatment; judging from the results we have obtained with sodium bicarbonate, it is evident that the treatment must vary with every variety of gastritis.

The strong bicarbonate waters, and especially large doses of these waters, are beneficial only to patients with hyperpeptic gastritis. When the evacuation of the stomach is delayed, as is generally the rule in these cases, the water should be administered three or four hours after meals. In the gastritis of the hypopeptic type light mineral waters should be chosen; their administration should take place about an hour before meals. If the bicarbonate waters are strong, then the dose should be small.

Intense hypopepsia and apepsia appear to contraindicate the alkaline waters, unless their use is clearly demanded by the state of the general nutrition.

Only patients with excessive nitrogenous excretion should be sent to the stronger springs, and in certain cases the condition of the urine, rather than that of the digestive tract, should determine the choice of the water.

Organic diseases, as cancer and acute ulcer, are contraindications to the employment of alkaline waters, especially the stronger varieties. In ulcer of long standing the waters may be useful; at least they are not contraindicated.

Chronic hepatic congestion and biliary lithiasis are the affections of the liver amenable to the treatment by stronger alkaline waters. In this respect Vichy is a formidable rival of Carlsbad. Successes would be still more frequent than they are if arrangements could be made between the physician and the hotel-keepers by which the patients could be made to follow an appropriate regimen.

Because of their ability to increase the secretions of all mucous membranes the sodium bicarbonate waters are employed in all chronic catarrhal inflammations. But in these conditions they are inferior to the mixed chloride waters.

Uterine inflammations, whether complicated or not by neuroses, are treated at the milder mineral springs, as at Andabre (Aveyron). Rheumatism responds only in rare, and as yet ill-defined, cases to the treatment of sodium bicarbonate waters. As to gout, the opinions are conflicting. The strong waters (Vichy, Vals) appear to modify the predisposition to gout and to retard the development of gouty symptoms. They are especially applicable to those cases presenting an excessive nitrogen excretion (excess of urea, total nitrogen, phosphoric acid, and urates). In the frank forms of gout they are indicated as long as the urine retains these characters.

When, however, there is a tendency to sub-excretion of nitrogen, indicating chronic and atonic gout, recourse must be had to the milder waters, or the use of these agents must be abandoned altogether. Uric acid or oxalic acid gravel, as well as renal colics, are manifestations of the same general state. They may be treated with the strong or weak bicarbonate waters, preferably cold springs, such as Célestins at Vichy. But they respond better to the diuretic waters, soon to be considered. Diabetes is also amenable to the treatment by sodium bicarbonate waters; clinical experience has shown the favorable action of Vichy, Vals, and others in this disease.

The explanation of this effect is yet to be found. Perhaps it is due to the improvement in the digestion. The fact that improve-

ment occurs in hyperpeptic as well as in hypopeptic or apeptic states is to be explained rather by a stimulation of the pancreatico-duodenal than of the gastric digestion. There may be a heightening of the hepatic functions.

The use of the stronger waters in diabetes is permissible only in non-cachectic and non-tuberculous individuals.

The close relations existing between digestive errors and the appearance of albumin in the urine explain the benefit which some albuminuric patients obtain from the bicarbonate waters. The improvement is seen only in cases with gastric troubles or when the albuminuria is related to the presence of urate infarcts in the kidneys. Parenchymatous nephritis is a contraindication, and chronic interstitial nephritis derives benefit from the waters only when it is of uric acid origin. At certain springs malarial cachexia and dyspeptic chlorosis are treated. In malarial cachexia associated with splenic and hepatic congestion there exist digestive errors that are favorably influenced by the use of the waters. But the change of scene, the new hygienic conditions, and the external measures have a large if not preponderating influence in the "cure."

Chlorosis, which is frequently combined with a hyperpeptic state, may in some cases be benefited by the chalybeate sodium bicarbonate waters, such as those of the Mesdames spring at Vichy.

Calcium Waters. Certain authors have described quite properly under the name of alkaline, earthy, or calcic waters a distinct group of mineral waters, which comprises those waters that in the French classification are designated as calcic and magnesium bicarbonated, calcic, sulphated, and mixed carbonated and sulphated waters.

The calcic waters have a number of marked characters in common. They are all cold and feebly mineralized; and the contained principles play so unimportant a *rôle* physiologically that the class might be placed in the indeterminate waters.

The benefit derived from their use appears to be based more upon the method of administration than upon any medicinal qualities. Their composition is characterized by the presence and predominance of salts of calcium and the absence of other minerals. In some springs bicarbonates of calcium and of magnesium are found; in others, the sulphate of calcium. Two classes of springs might be established, were it not that in many cases both bicarbonates and sulphates occur together.

Many of the waters are gaseous on account of the presence of car-

bonic dioxide. Nearly all are employed internally by the method of "lavage."

ALKALINE EARTH, OR CALCIC WATERS.

Name.	Bicarbonate of calcium and magnesium.	Sulphate of calcium.	CO_2.	Total.	Temp.
Pougues, Saint Léger	2.20	...	2.11 gr.	5.500	12° C.
Contrexéville, Povillon	0.43	1.160	59 c.c.	2.380	10
Vittel, Grande Source	0.79	0.410	1.739	1.00 c.c.	11
Capvern	0.05	1.091	...	1.604	22
Aulus	0.75	1.400	0.11 gr. c.c.	3.610	18
Wildungen (Prussia), George Victor	1.24	...	1.322	1.440	01
Driburg (Prussia), Heristerquelle	1.51	1.000	1.043	2.720	10

Among the French waters Pougues deserves special attention on account of the relatively high proportion of minerals.

We might also add to the list some of the less important waters, such as Sermaize (Marne), Evian (Haute-Savoie), of which the total quantity of dissolved minerals is less than 1 gramme; Alet (Aude), an export water of feeble mineralization; Foucaude (Hérault); Oriol (Isère); Cransac (Aveyron), one of the most highly mineralized waters; Encausse (Haute-Garonne), strong in calcium sulphate, etc.

PHYSIOLOGICAL EFFECTS. The calcium salts are unimportant physiologically, for although the fluids and solids of the body contain a considerable quantity, enough for the needs of the system is derived from the ordinary aliments. Some doubt exists as to the action of the salts of lime on the digestion. The accepted view is that the bicarbonate is decomposed in the stomach to form the chloride and lactate of calcium, as well other salts of lime. Yet it need not modify digestive processes; it may merely act, if in sufficient quantity, as an antacid. The question, however, is probably not definitely solved.

In studying the subject it will be necessary, first, to determine the effect of very large quantities of feebly mineralized waters, according to the mode of administration in vogue at a number of resorts, as Contrexéville, Vittel, Capvern, Evian, etc. Secondly, it will be important to investigate the influence upon digestion of waters of comparatively high mineralization, such as those of Pougues, which contain almost 5 parts of mixed principles per 1000.

This subject becomes the more interesting since the chemical researches of Winter indicate that the calcium salts play a part in gastric fermentation.

The treatment at Pougues produces a slight stimulation of the processes of digestion, and for this reason we agree with Bovet, who advises the use of these waters in hypopepsia.

Sulphate of calcium is indigestible; its presence in pure sulphated waters renders them laxative. The salts of magnesium, which are not present in large quantities, have a similar action, and are at the same time antacid, like the bicarbonate of calcium. Yet many of these waters, even the pure calcium sulphate waters, may be borne in large quantities and exercise the same lavage effects as the less highly mineralized waters. Several act in these doses on the intestines and aid in their evacuation.

The action of calcium waters on nutrition does not differ from that of ordinary water. This statement is not controverted by the results of the researches of certain physicians of Evian and of Vittel.

The long-established and universal reputation of the lime waters in calculous affections renders it probable that they possess a dissolving action on uric acid. This is the view recently advocated by L. Lehmann (1889), whose studies were made with the Pavillon water, at Contrexéville, and the bicarbonate spring Hélèna, at Wildungen.

THERAPEUTIC USES. The diseases influenced by the lime waters are few in number.

Of chronic gastric conditions it appears that those complicated with chronic constipation are most markedly benefited. Intestinal atony may be overcome, at least temporarily, at such springs as Contrexéville. Chronic gastritis of the hypopeptic type may be improved at Pougues, where only small quantities of water are taken. It is possible that these waters have a medicinal action in these cases. (The Pougues waters contain 2.995 grammes of various bicarbonates of calcium, sodium, magnesium, potassium, lithium, and iron.)

The special value of the less highly mineralized waters is to be found in cases of gravel, especially those of uric acid, and in chronic catarrhal affections of the urinary passages. The method of administration consists in the ingestion on an empty stomach of very large quantities of the waters.

At Contrexéville, for example, the patients begin with three or four glasses and gradually increase to eight or ten; then the quantity is again decreased. This brings about diuresis and has also a laxative effect; sometimes constipation is observed. According to Treuille, the urine exceeds by one-third the amount of water ingested. Rodet, of Vittel, contents himself with saying that the diuresis is

proportionate to the amount of water consumed. Not rarely small calculi are expelled with the urine.

In cases of vesical calculi the treatment develops the characteristic signs of the disease and thus becomes a diagnostic agent.

The expulsion of calculi and the free flushing of the urinary passages brings about an improvement or cure of the complications of gravel, such as cystitis, prostatitis, or pyelitis.

At Vittel the waters contain an abundance of carbonic dioxide, which renders them sedative in irritable patients. In chronic inflammations of the urinary passages secondary to gravel or calculous states the waters of Evian seem to be particularly useful.

Many gouty subjects, as well as such as are merely predisposed to gout, are sent to these watering-places on the belief that free flushing of the kidneys and a greater elimination of uric acid cannot but be of advantage in such cases. The recent researches of Chiaïs tend to render these somewhat vague indications more definite. At these resorts, where it is customary to drink large quantities of the waters (Vittel, Contrexéville), the nitrogenous excretion is increased. According to Chiaïs, patients who have presented an excessive nitrogen excretion should not go there. The treatment at such places should be reserved for those with defective nitrogen excretion, or in whom the nitrogenous substances are not completely oxidized.

Researches of the nature of those of Chiaïs cannot be too highly encouraged, for a large number of such data are required before we can place the indication for the use of mineral waters on a sound basis.

Sulphate Waters. The fifth group of mineral waters comprises the sodium and magnesium sulphate waters.

Magnesium and sodium sulphate have a special effect on the digestive tract, which is generally attributed to the modification in osmosis that is brought about by all saline solutions.

Many writers, as we have already stated, make a single group of all the saline waters. But if we disregard the effects of large doses on the intestines and compare the influence exerted by moderate doses, especially on the stomach, we shall find that the sulphate waters differ widely in their action from the sodium chloride waters.

The sulphate of magnesium and sodium waters may therefore be taken as a type of a natural group. This group is divisible into sub-groups. First, the pure sulphates, or bitter waters of the Ger-

mans, which are true mineral waters, and, secondly, the mixed sulphates.

The pure sulphate or bitter waters only cause purgation; they are largely exported.

According to the greater or less abundance of salts they may be classified as strong and mild. They contain sulphate of sodium and of magnesium and small quantities of sulphate of calcium, carbonate of magnesium, chloride of sodium, and in some instances free carbonic dioxide. The majority are highly mineralized.

The most famous, such as Püllna, Seidlitz, and Saidschütz (Bohemia), are obtained by an artificial process; these waters, therefore, belong to the class of lixiviated waters. At Püllna, for example, the rain-water percolates through layers of marl, containing various salts, and is collected in wells of about three yards' depth, lined with wood. At Friedrichshall the waters traverse secondary strata containing masses of basaltic rocks, and are also collected in wells. They contain as much sodium chloride as bitter sulphates.

The variability of the strata through which this class of waters passes explains the diversity in composition. The waters of Birmensdorff, in which, as in those of Seidlitz, magnesium sulphate predominates, emerge from reservoirs, where masses of this salt have been found in the neighborhood of deposits of gypsum.

PURGATIVE SULPHATE WATERS.

Name.	Sulphate of magnesium.	Sulphate of sodium.	Sulphate of lime.	Chloride of sodium.	Chloride of magnesium.
Montmirail (Vaucluse)	9.3	5.10	0.20	...	...
Miers (Lot)	...	2.67	0.95	0.02	0.70
Rubinat-Condal (Spain)	...	...	...	...	...
Victoriaquelle (Austria)	32.4	20.90	1.60	...	...
Franz-Josephquelle (Austria)	24.6	24.00	1.85	...	1.67
Hunyadi-Lazlo (Austria)	24.2	22.80	1.60	...	...
Hunyadi-Janos (Austria)	22.3	22.50	...	1.30	...
Birmensdorff (Switzerland)	21.1	6.79	0.40	...	...
Seidlitz (Bohemia)	13.5	...	1.40	...	0.40
Püllna (Bohemia)	12.1	16.10	0.30	...	2.10
Saidschütz (Bohemia)	10.9	0.10	1.30	...	0.30
Friedrichshall (Saxe-Meiningen)	5.1	6.00	1.30	7.69	3.90

The only French water that can rival the foreign purgative waters is that of Montmirail-Valqueyras.

All the waters of this group are transportable, but can all be replaced by an equivalent dose of neutral salts; as purgatives they are merely a luxury.

Their abuse, as also that of the purgative salines, leads to chronic gastritis and apepsia.

The only pure sulphate spring at which treatment may be carried out is that of Miers. It would be of great importance to know what effect the waters at Miers produce on digestion, for sodium sulphate is certainly one of the most energetic stomachic agents.

Chalybeate Waters. In many mineral waters there exists a small quantity of iron—enough, indeed, to be of some influence. As an example, we may cite the Mesdames Spring at Vichy, which is, strictly speaking, a sodium bicarbonate chalybeate spring.

Under the name of chalybeate waters we include only those in which the iron is present in sufficient quantity to produce some therapeutic action, while the other mineral principles are present, from the therapeutic standpoint, in nominal amounts.

According to Gerdy, chalybeate waters are found wherever iron is found in a finely divided state in association with mould or decaying vegetable matter. The iron is dissolved especially by waters supersaturated with carbon dioxide in contact with strata rich in the oxide of iron.

A carbonate of iron is produced which, in the presence of alkaline bicarbonates, forms, as shown by Lefort, soluble double salts.

Besides carbonated chalybeate waters, others are found, such as those containing ferrous sulphate, usually in association with alkaline sulphates.

Berzelius has shown that certain springs regarded as carbonated really contain the crenate of iron. The chalybeate waters have been divided into three classes—the bicarbonate, the crenate, and the sulphate waters, a classification adopted by Le Bret.

It seems to us unnecessary to establish more than two classes, the first comprising the bicarbonate and crenate waters, the two being frequently associated; and, secondly, the chalybeate sulphate waters, which differ sufficiently from the preceding to warrant their being placed in a separate class.

All chalybeate waters proper are cold. A certain number of warm springs employed externally should be classed with the indeterminate waters.

The chalybeate waters are feebly mineralized, the best known containing only 6 to 7 centigrammes of the carbonate of iron per litre. In many the quantity is 3 or 4 centigrammes, or even less.

The chalybeate sulphates are relatively rich in mineral principles.

A few springs contain arsenic in the form of arsenate of iron.

There is in many chalybeate waters a sufficient amount of carbonic acid to render them acceptable and easy of digestion.

Among the other substances found in chalybeate waters may be named carbonate of calcium, of sodium, and of magnesium, which are found in small quantities normally. There are, indeed, waters the fixed principles of which are scarcely above 0.5. The sulphate waters must be excepted, as they may contain 5 grammes.

CARBONATED FERRUGINOUS WATERS.

Name.	Carbonate of iron.	CO_2.	Secondary elements.
Le Bauche (Savoy)	0.14	0.035	Crenate of lime and carbonate of magnesium.
Orezza (Corse)	0.12	1.248 c.c.	
Forges-les-Eaux (Seine-Iuf.), s. Cardinale.	0.068	0.22 gr.	-
Neyrac (Ardèche), s. des Bains . .	(Crénate.) 0.014		Alkaline bicarbonates.
Renlaigue (Puy-de-Dôme) . . .	0.08	1.695 c.c.	Alkaline bicarbonates.
Bussang (Vosges), s. des Demoiselles .	0.029	0.969 gr.	Bicarbonates of sodium and of lime.
Saint Pardoux (Allier)	0.02 (Crénate.)	1.248 c.c. c c.	
Kœnig Ottobad (Bavaria) . . .	0.79	0.953	Alkaline carbonates
Elœpatak (Prussia) . . .	0.29	1.254	Ibid.
Spa (Belgium), s. du Pouhon . .	0.19	1.288	Carbonate of sodium.
Cudova (Silesia), s. Trinkquelle . .	0.11	1.300	
Rippolsdau (Prussia), s. Wenzequelle	0.11	0.559	
Schwalbach (Prussia), s. Stahlbrunnen	0.08	1.570	
Pyrmont (Prussia), s. Hauptquelle .	0.07	1.271	
Saint Moritz (Switzerland), s. Paracelsusquelle.	0.03	1.515	

FERRUGINOUS SULPHATE WATERS.

Name.	Sulphate of iron.	Secondary elements.
Auteuil	0.715	Various sulphates, sulphate of alumina and of iron.
Vals (Ardèche), s. Dominique . .	...	Arsenic.
Parad (Hongrie), Alaunquelle . .	4.400	Various sulphates.
Hermannsbad (Saxony) . . .	4.180	Various sulphates.
Roncegno (Tyrol)	2.380	Various sulphates.
Alexisbad (Prussia), Selkebrunnen .	0.050	0.10 of chloride of iron, various sulphates.

PHYSIOLOGICAL EFFECTS OF FERRUGINOUS WATERS. Having briefly considered their chemical characters, we may now take up the physiological and therapeutical properties of the ferruginous waters. The class we shall begin with is that of the bicarbonate waters. These are clear, transparent, non-odorous, and have an astringent taste recalling that of iron, but corrected by the presence of carbonic dioxide.

Special researches on the absorption of the iron of mineral waters and upon the effects which it produces upon the digestive processes have not been made. It is, indeed, one of the numerous lacunæ which a more complete study of the action of mineral waters should fill. The sulphate waters which contain the alkaline sulphates, alum, and sometimes arsenic (Dominique de Vals), have a more pronounced astringent taste than the others and should only be taken with caution, and as a rule diluted. It is interesting also to determine the effects which they have upon the digestive tract.

The chalybeate waters are also employed in the form of baths. Although the important factor is the disengagement of carbonic dioxide, they determine effects which differ from those of the baths containing free carbonic dioxide. They are more stimulating.

Therapeutic Uses for Ferruginous Waters. Since iron is the specific remedy for chlorosis, the transportable ferruginous waters have been prescribed for this disease, and patients have often been sent for treatment to chalybeate springs. What is the value of this practice? The first question to be determined is whether chlorosis can be cured by their use; for, as we have observed, and according to the opinion of others who have published treatises on mineral waters, particularly Le Bret, the use of chalybeate waters does not cure chlorosis. Indeed, some cases are aggravated by their employment.

Let us see why these waters, which are known to contain iron, fail. The following are the principal reasons: First, the ferruginous waters are digested with difficulty. Caulet, who has studied the subject thoroughly, divides individuals who use the waters into two categories: those who digest them and those who do not tolerate them well. Among the latter the use is followed by a feeling of weight in the epigastrium, and then by a plethoric state and constipation. The evacuations assume the characteristic black color.

In those who seem to digest the waters the following phenomena are produced: First, congestion of the head; sometimes sufficiently pronounced to necessitate revulsive agents for the purpose of moderating them. Then an increase of appetite, even up to bulimia. There is also increased diuresis, though the dejecta preserve their normal color, a fact which indicates that the iron is absorbed. Nevertheless if the doses are increased the feces become black. Eventually at the end of a variable period, the continuance of the treatment leads to a saturation of the system, which manifests itself by fatigue, lassitude,

malaise, cephalalgia, and by aversion to the waters, and then by furunculosis and acneiform eruptions. We may interpret these interesting results as follows: The chalybeate mineral waters exercise a marked action upon the digestive tract. In those cases where they appear to be digested (and they are the exception) they sooner or later excite phenomena of intolerance. Further, all the chlorotics present abnormalities of digestion, and the majority of them do not dispose at all, or imperfectly, of the ferruginous waters. Scheuer recognized the fact that many of the chlorotic patients do not digest the waters of Spa. He attributes this to dilatation of the stomach, a condition which, at the time he wrote, was considered as the disease upon which all forms of dyspepsia depended. But dilatation is only one of the symptoms of the gastropathy of chlorosis. It is generally associated with a more or less pronounced hyperpepsia with increase of the secretions and slowness of digestion, a state accommodating itself neither to iron nor to the waters, taken upon an empty stomach. The second cause of the failure of the ferruginous waters in chlorosis should be attributed, it seems to us, to the feeble intensity of their medicinal action. To repair the diseased condition of their blood, chlorotic patients need a fixed and rather large quantity of iron. It should be remembered that in pronounced chlorosis the deficit of iron in the blood is very considerable. Estimating the total amount of iron in the blood of a healthy adult as three grammes, the proportion in a case of chlorosis, with moderate anæmia, sinks to $1\frac{1}{2}$ grammes. In more pronounced cases, it may fall to one gramme, or even to 0.75. This is a very interesting pathological fact. The ferruginous waters, even those most strongly mineralized, contain only 0.7 gramme of iron, that is to say, a very small proportion. These are, therefore, incapable of furnishing a sufficient quantity of iron even if we admit that all of the metal which they contain is absorbed and fixed by the blood, which is far from probable. The pharmaceutical preparations are far superior. They offer the advantage of permitting the introduction of a large quantity of iron, and of being tolerated for a longer time, at least until the restoration of the blood is complete.

The third reason of the non-success of the treatment at chalybeate springs depends upon the fact that the extrinsic conditions obtaining at the stations are more harmful than useful. Whilst in a large number of morbid states the cure at watering-places acts favorably by virtue of the extrinsic conditions arising from the change of air, the exercise, and the alteration of the regimen, in chlorosis these

diverse factors play a rather harmful *rôle,* at least, in the majority of cases. Thus chlorotic patients who are at the same time neurasthenic, not only do not support exercise and fatigue, but frequently need absolute rest, particularly at the beginning of the treatment. On the other hand, by reason of their dyspeptic state, many of them should be subjected to a very severe regimen which differs essentially from that at hotels. Finally, baths and hydrotherapy are means which should be employed only at an epoch when the restoration of blood is already fairly advanced, when strength has returned sufficiently to make a reaction possible.

A long experience permits us to formulate our conclusion as follows: Chlorosis is treated better at home than at climatic resorts or chalybeate springs. In a number of cases where certain forms of medication claimed as useful had been vainly tried, we succeeded easily and quite rapidly without removing the patient from his habitual surroundings. Being given a well-marked case of chlorosis, the first thing to do is to impose absolute rest in bed for two or three weeks. The necessity for this repose is greater the more pronounced the anæmia, and the more marked the neurasthenic state. In the second place, a severe alimentary regimen should be insisted upon, being always controlled by the state of the stomach, and the latter should always be determined by the analysis of the gastric juice. The diet which is best suited consists of milk and raw meat. This is, moreover, indicated by the hyperpeptic state of the stomach, so common in chlorosis. The complete rest and the dietetic regimen are very grateful to the patients, who nearly always have been over-exercised and over-fatigued. The two measures indicated are almost alone sufficient to bring about a certain degree of amelioration. When at the end of about eight days the dyspeptic state, as revealed by palpation, by percussion, by the determination of clapotage, and by the chemical analysis, etc., is such as one generally finds in these cases, that is to say, a moderate degree of hyperpepsia, with slow digestion and beginning dilatation, the administration of iron may be begun.

The preparation to which we give preference is the protoxalate (oxalate of the protoxide of iron), which is easily soluble in the presence of the hydrochloric acid of the gastric juice. We prescribe it in doses of from 3 to 6 grains, taken at the meal. The preparation does not constipate. If constipation exists, it is combated by mechanical laxatives, such as the mucilaginous cereals, or by enemata. The general regimen is maintained, but little by little, as the improve-

ment progresses, the patient is permitted to resume a more normal diet. At the end of fifteen days or a month, according to the nature of the case, the patients regain their color, recover their strength, and are able to get up. They may then be allowed to take short promenades in the air, and after five or six weeks the cure will be far advanced, if not achieved. In those cases where the gastric condition is accentuated, the treatment of chlorosis is more difficult. We have then to deal with two opposing states: On the one hand, hyperpepsia with hyperacidity and pronounced dilatation, perhaps even complicated with ulcer; on the other hand, a condition of chronic gastritis of the hyperpeptic type, arising from various causes, such as badly regulated diet, the use of agents depressing the activity of the stomach, etc. In both of these conditions the patients are markedly dyspeptic. Before being placed on iron, which is often badly borne, they should be treated as cases of simple dyspepsia. The iron should only be given at the time when a sufficient improvement of the gastric state has been obtained. When a persistent hypopepsia exists, hydrochloric acid may be used to assist the digestion of the iron. The latter is then given before meals; the hydrochloric acid after meals.

This mode of treatment has always been crowned with success in our hands, and we can, therefore, confidently recommend it.

From what has been said, it follows that chlorosis, and especially chlorosis with marked dyspepsia, are not indications for the use of chalybeate waters. We should, however, not conclude that these waters are without value in anæmias or even in certain mild forms of chlorosis, but the indications for their use are not precise and depend upon very variable circumstances. They will, in our opinion, remain obscure as long as the physiological and pharmaco-therapeutical effects, particularly those upon the digestive tracts, are not better understood.

According to clinical observations certain forms of *dyspepsia*, especially those complicated with chronic diarrhœa, are benefited by chalybeate waters. Thus the physicians of Forges and a number of other resorts have as their *clientèle* a large number of dyspeptics. In these cases the air, the exercise, the balneotherapy and hydrotherapy play an evident part in the effects of the waters. But we still lack precise data concerning the conditions in which the iron-containing waters are useful. It is possible that we shall in the future find chronic or hypopeptic gastritis, with or without mucous transforma-

tion of the glandular apparatus of the stomach, amenable to this form of medication.

Another indication for chalybeate waters is *secondary anæmia*, such as post-hemorrhagic and puerperal anæmias, those secondary to traumatism, the anæmia of convalescence, and all other conditions in which the restoration of the blood tends to take place spontaneously, or at least needs only good hygienic conditions.

Certain uterine affections, as dysmenorrhœa and the metrorrhagias with secondary anæmia should be included. In these conditions the indication is not to cure the anæmia but to remove the cause, and for this purpose the chalybeate waters are inferior to many others. Certain neuropathic conditions and different forms of chronic rheumatism are sometimes improved at ferruginous springs. But here the external treatment is the more active agent.

We may conclude the consideration of the pure chalybeate waters—that is, those employed as beverages—by stating that they have no precise indication. Either they are useless or inadequate, as in true chlorosis, or they act simply as ordinary mineral waters—*i. e.*, chiefly through extrinsic conditions. It is, therefore, unnecessary to insist at this time upon a specialization of the various resorts. The sulphated waters appear to be appropriate to the treatment of chronic diarrhœas, and even, according to some writers, to the treatment of chronic gastric catarrh and gastric ulcer. These assertions, however, are not supported by sufficient proof.

Indeterminate Waters. Under the name of indeterminate waters (Durand-Fardel), simple mineral waters (Le Bret), and other names, we understand those feebly mineralized waters which seem to act chiefly by reason of the mode of their administration, and very frequently also by their warmth. We also include in this group the gaseous acidulated waters of certain writers.

The group then comprises two classes, the simple mineral waters, thermal or not thermal, used especially or exclusively for external use, and the gaseous acidulated waters. The simple mineral waters are waters the temperature of which varies from 90° to 130° F. They are generally warm, feebly mineralized, and sometimes contain even a smaller amount of fixed principles than potable water. The elements found in them are especially sodium bicarbonate and sodium chloride. The absence of lime and magnesium gives them a marked softness, so that they may be taken as beverages or employed as baths. The gases found in them are oxygen and nitrogen. Carbon

dioxide is not abundant. Sometimes traces of hydrogen sulphide and of organic matters are found. Minute quantities of arsenic, of lithium, and of iron may be present.

Physiological Effects of Indeterminate Waters. It is characteristic of these waters that they produce therapeutic effects which cannot be clearly ascribed to any medicinal or chemical action. The majority of the hydrologists consider, however, that these waters differ from the ordinary potable waters. They attribute to them a physiological action and therapeutic virtue of a special kind distinct from that obtained from all other waters. But to what factors are these effects due? We have already examined this question, and we have seen that the electric state of mineral waters has been invoked in explanation of these effects. The action of electricity, the value of which is perhaps great, should not make us neglect the other physical or mechanical factors capable of exerting an important influence. The temperature appears to be at times the most active of these factors. On the other hand, the special arrangements at certain stations appear to contribute, by the originality of their disposition, to the success obtained. Mud-baths and special methods of bathing, such as prolonged immersion or the bath in running water, are employed, and no doubt play a part. It appears, then, very probable that in a certain number of cases, at least, the beneficial effects of the cure should be ascribed not to any special physio-chemical effect, but to the peculiar modes of treatment in vogue. We should add that the climate and the accessory conditions, of which mention has been made when speaking of the treatment by mineral waters in general, may become important factors, especially in mountain resorts.

Indeterminate Waters.

Name.	Temperature.	Total.	Altitude.
Aix (Bouches-du-Rhône)	20–36° C.	0.57	204 M.
Sail-les-Bains (Loire), s. Duhamel	34	0.42	250
Ussat (Ariège)	32–40	1.27	428
Mont-Dore (Puy-de-Dôme)	10.5–44	1.60	1046
Bains (Vosges)	24–48	0.50	306
Bagnères-des-Bigorre (Htes-Pyrénées)	20–50	2.25	556
Luxeuil (Haute-Saône)	28–52.5	0.54	404
Néris (Allier)	43–58	1.26	260
Dax (Landes)	43–64	1.02	40
Plombières (Vosges)	26–68.6	0.32	621
Chaudes-Aigues (Cantal)	31–82	0.67	650
La Malou (Hérault)	21.5–48	0.50–1.75	
Saint Amand (Nord)	23	1.50	
Barbotan (Gers)	21–35	0.131	
Saint Christau (Basses-Pyrénées)	13.5–14	0.30	300
Badenweiler (Forêt Noire)	26.4	0.33	422

Name.	Temperature.	Total.	Altitude.
Schlangenbad (Hesse-Nassau)	28–32° C.	0.33	313 M.
Ragatz (Switzerland)	35.3	0.29	521
Pfaeffers (Switzerland)	37.5	0.29	605
Römerbad (Styria)	37	0.08	237
Wildbad (Würtemberg)	33.7–39.5	0.54	430
Lippspringe (Prussia)	21	2.40	
Inselbad (Prussia)	18	1.38	
Weissenbourg (Switzerland)	26	1.39	878
Bormio (Italy)	33–41	0.98	1448
Bath (England)	42–47	1.9	
Gastein (Austria)	43–48.7	0.32	1047
Tœplitz (Bohemia)	28–49	0.64	220
Louèche (Switzerland)	57	1.9	1300

The number of stations belonging to this group is very large, and it could be increased, for a number of waters classed in other groups might properly be included in this. The incorporation of certain waters tolerably rich in mineral constituents, such as Bagnères-de-Bigorre and Lippspringe, is explained by the definition which we have adopted. All the waters employed for external application, even when they are strongly mineralized, cannot be placed elsewhere. For this reason we include La Melou, Saint Amand, and Saint Christau.

We shall not dilate upon the physiological and therapeutic effects which can be obtained by means of the indeterminate waters. It is only necessary to repeat here that which has been said regarding the general subject of mineral waters. Depending upon the means employed, upon the temperature, and also, perhaps, upon the physical properties of the waters, phenomena of stimulation or of sedation are produced. Frequently the latter result is only achieved after the termination of a period of more or less intense excitation. This is the case, for example, at Néris.

Therapeutic Uses of Indeterminate Waters. Considered in their totality, the indeterminate waters are appropriate in the treatment of all chronic diseases. Nevertheless, among the many stations belonging to this class we can recognize certain special features, which in some instances depend merely upon the peculiar methods adopted.

Among the diseases amenable to this form of treatment *rheumatism* in all its forms stands first. The majority of the thermal stations may be utilized in these cases, but even they should not be placed upon the same rank. Those should be chosen in which the management is the best, while the different forms of rheumatism should always receive special attention. Unfortunately, in regard to this last point, the importance of which is readily apprehended, the empirical facts collected up to the present time are far from affording

us satisfactory enlightenment. When the rheumatism is acute, frank, or manifests itself by repeated attacks which leave no articular lesions behind them, the thermal treatment is generally of restricted utility. Yet if there is no cardiac lesion, or if only a slight one exists, the attempt can be made to modify the rheumatic diathesis. The patient should, under these circumstances, be sent to stations the waters of which have a sedative action, such as Chateauneuf (which has been placed in the class of bicarbonate waters, but at which the treatment consists solely of the pool-baths), where good results are obtained, but which is not provided with the necessary comforts; also to Bains-en-Vosges, Aix-les-Bains (classed among the sulphurous waters), Bourbon-Lancy (classed among the chloride waters).

Very irritable persons in whom it is important to secure a calmative effect should be sent to Néris, Plombières, Bagnères-de-Bigorre, Bourbon-Lancy, or Ragatz-Pfeffers. Néris is the principal French resort. It enjoys a salubrious climate, and the various methods of external treatment in use appear to possess some importance. The water of Néris, which is hot, is reduced to 102° by means of a current of cold water conducted through a tube surrounding the conduits. Exposed to the air, the water becomes still cooler, the temperature falling to 94°. The treatment consists in the more or less continued employment of warm baths (90° to 94°). Sometimes these baths are greatly prolonged, having exceptionally a duration of four to five hours. The treatment, at first stimulant, becomes finally sedative.

Plombières, one of the most important stations by reason of the great abundance of springs and its excellent arrangements, is suited to sanguine and irritable persons. The treatment is particularly useful in the painful forms of rheumatism, and in those imperfectly understood manifestations to which the name of chronic visceral rheumatism has been applied. In the atonic forms of chronic rheumatism, when a strong stimulation is not to be feared, Saint Amand, Barbotan, and Gastein are the stations of choice.

Dax, to which reference has already been made in connection with the mud-baths, has an especial influence in these cases. Where chronic rheumatism attacks a lymphatic subject, the mud-baths of Saint Amand and Barbotan are perhaps less active. Gastein is a remarkable resort. With its waters, the mineralization of which is practically nil, very marked effects are obtained. The baths are short in duration, and are taken in small pools or ponds, with the water at a temperature of 100° to 102°. The patients experience at

first a sensation of well-being; their appetite increases and their *morale* improves. But about the twentieth or twenty-fifth day they are seized with diverse morbid conditions in the bath, consisting in chills, nausea, often excitement, insomnia, anorexia, thirst, slight fever, and nervous erethism. The general result of the treatment is ultimately manifested by an improvement of the health. Among the stations appropriate to the treatment of chronic rheumatism we should also mention Tœplitz-Schönau, Louèche, and Wildbad. All the nervous manifestations associated with the disease, as neuralgias, both peripheral and visceral, and the so-called rheumatic paralyses, are treated at the resorts named.

Gout, which may be placed beside chronic rheumatism, lends itself to the same mode of treatment. The stations of choice are Châteauneuf, Tœplitz, Bath, etc.

The largest *clientèle* of the indeterminate springs is perhaps taken from those afflicted with the various forms of *neuropathy.* The most renowned stations in the treatment of the neuroses are Néris, Dax, Ussat, La Malou, and Gastein. Hysteria is treated chiefly at Néris. Gastein has acquired a reputation in the treatment of the depressing forms of neuroses. Remarkable results have been attained there in nervous exhaustion consequent upon cerebral overwork, in the debility resulting from venereal excesses, in hypochondriasis, persistent insomnia, and spermatorrhœa; in short, in all the diverse varieties of neurasthenia, particularly in the primitive form, that are not symptomatic of visceral disease. The neuropathies characterized by irritability and excitement find at Dax sedative influences, due probably to the constancy of the temperature as well as the balneological procedures to which they are subjected.

At Ussat, in Ariège, a resort situated 1500 feet above sea-level, cool baths are employed, by means of which a very pronounced calmative effect is procured.

The indeterminate waters which exercise a local influence are suitable for external applications in *chronic skin diseases.* The moist affections, eczema and impetigo, are treated at Louèche-les-Bains and at Avène. At the former, which is situated at an altitude of about 5000 feet, the patients are subjected to a special form of treatment. This consists in pool baths of progressively increasing length, taken at a temperature of 95° F. Beginning with a sojourn of one-half to one hour, the duration is prolonged until the patient eventually remains five to six hours per day in the bath in two *séances.* After

leaving the bath he lies down for half an hour or more. When the effect determined by this mode of bathing has appeared, the patient is subjected to baths of a progressively decreasing length. The effect consists in a more or less generalized erythema, complicated at times by the production of pustules and of fever of variable intensity. When this reaction fails, the treatment rarely succeeds. Apart from eczema and impetigo, good results are also obtained in psoriasis and acne. The dry cutaneous affections are treated at Néris, Plombières, Bagnères-de-Bigorre and Saint Amand.

The indeterminate waters are also prescribed in *dyspepsias* associated with painful phenomena, as gastralgia and enteralgia. It should be remarked, however, that these symptoms are very often dependent upon organic disease, which should be first recognized and treated. The employment of balneological and hydrotherapeutic procedures—that is, of revulsive measures—is frequently indicated in the chronic form of diseases of the digestive tract, and the results which have been obtained in certain cases, as at Plombières and analogous resorts, are often due as much to the resolving effects of the treatment as to a more or less indeterminate action exercised upon the nervous system.

The waters have also been employed in the treatment of affections of the *genito-urinary organs*.

The uterine diseases of subacute character, and complicated by great nervous irritability, may be modified by the waters of Néris and of Ussat. In the chronic and asthenic forms preference is given to Plombières, Bagnères-de-Bigorre, Bagnoles de l'Orne, Avène, and Bourbon-Lancy.

Gaseous Acidulated Waters. The name gaseous acidulated has been given to the waters having no fixed principles, but rich in carbonic dioxide gas. Carbonate of sodium, chloride of sodium, and carbonate of lime are the chief elements. The carbonic acid gas varies in proportion from 500 to 1500 cubic centimetres. The majority of these waters are cold; some, as those in Auvergne, have a somewhat elevated temperature. Nearly all possess an agreeable and piquant taste resulting from the presence and disengagement of a part of the carbonic dioxide.

Physiologic Effects of Gaseous Acidulated Waters. The physiological effects depend upon the gas. The waters stimulate the stomach, the stimulation being general, affecting at the same time the mucous membrane and the glands, the nerves and the mus-

cular coat. It would be interesting to verify this stimulation by experiment. The carbonic dioxide ingested is in part eliminated, in part absorbed. The proportion absorbed is, according to Quincke, very small, because of the high tension of the carbonic dioxide in the blood. This absorption is, however, demonstrated by the fact that the use of gaseous beverages, particularly of those which contain the fixed gas (the gaseous bicarbonated waters), determine phenomena of intoxication. The gaseous waters are also diuretic, a property which Quincke explains by the rapidity of absorption of the water in the presence of carbonic dioxide.

All these waters are agreeable table beverages, which can be utilized in cases of nausea and loss of appetite. They also appear to have the power of diminishing the duration of digestion. Have they anti-fermentescible properties? It is not definitely known, for the physiological and pharmaco-therapeutic effects determined by the transient or prolonged use of these gaseous waters have not been sufficiently studied. This, too, is one of the lacunæ in our knowledge which the future must fill.

The baths in gaseous waters produce a cutaneous stimulation which stands intermediate between that resulting from the employment of saline baths and that produced by water at high temperature. They apparently do not excite any central action; at least, their effects upon the heart are unappreciable. There is, moreover, no absorption of carbonic acid gas by the skin.

We should mention, in order to complete the subject, the existence of artificial gaseous waters, which are distributed in large quantity and sold often under the name of "natural waters." Durand-Fardel has called attention to the fact that these artificial waters do not retain the carbonic acid gas with the same tenacity as the natural waters. He inveighs against the excessive use of the gaseous acidulated waters, whether they are natural or artificial, But it is not yet known in what way they become prejudicial to health.

Gaseous Waters.

Names.	Free CO_2.
Desaignes (Ardèche)	1525 c.cm.
Saint Galmier, source, Noël	1520
Saint Pardoux (Allier)	1248
Châteldon (Puy-de-Dôme)	1165
Bussang (Vosges), s. de la Salmade	700
Condillac (Drôme)	400
Schwalbach (Prussia), Lindenbrunnen	1590
Apollinaris (Prussia)	1521

Names.	Free CO_2.
Reinerz (Prussia), Kaltequelle	1465 c.cm.
Wildungen (Waldeck), Georg-Victorquelle	1322
Cudowa (Silésia), Oberbrunnen	1298
Passug (Switzerland), Belvedraquelle	1076
Fidéris (Switzerland)	686

Mixed Complex Waters.

Apart from the waters in which the action of a medicinal principle predominates there exist quite a number of other interesting waters, the therapeutic properties of which seem to be dependent upon several principles. These waters can be ranged in a small number of groups, the study of which is generally taken with that of the relatively simple waters. We have given a list of these in classifying the mineral waters.

Sulphuretted Chloride and Chloride Sulphuretted Waters. The first of these groups is formed by the springs containing active amounts of sulphur compounds and chloride of sodium. Sodium chloride exists in small proportion in a large number of sulphurous waters; generally it plays no *rôle*, but when it attains a proportion of more than a gramme to the litre it contributes in part to the therapeutic action of the water. In some of these springs the quantity of salt becomes so large that the water presents the medicinal properties of the sodium chloride springs. It is this characteristic upon which the name of chloride sulphuretted water is based. Sulphuretted chloride waters are usually calcium sulphide or hydrogen sulphide. They also contain sulphates, and are distinctly more mineralized than the pure sulphuretted waters. In those springs where sodium chloride predominates the sulphur compound may be either hydrogen sulphide or sodium sulphide; at times both may be found.

Sulphated Chloride Waters.

Names.	H_2S	Sulphate of calcium.	Sulphate of lime.	Sulphate of sodium.	NaCl.	Total.	Temp.
	c.cm.						
Gréoulx, Guihert	0.020	0.044	0.480	0.148	1.290	2.250	19° C.
Saint Gervais, Torrent	3.040	...	1.100	1.688	1.776	5.028	39
Uriage	7.344	...	1.500	...	6.000	...	...
		Sulphate of sodium.					
Mehadia (Hungary), Herculeshad	...	0.080	...	...	3.820	...	44
Aix-la-Chapelle, Kaiserquelle	0.310	0.010	...	0.270	2.530	...	55
Baden (Switzerland)	0.060	...	1.350	0.280	1.620	...	50
Borcette (Prussia), Victoriaquelle	...	0.001	...	0.270	2.670	...	60
Helouan (Egypt)	4.700	...	0.210	...	3.200	...	30
Lostorf (Switzerland)	0.120	0.230	...	...	3.020	...	14
La Puda (Spain) (froide)	...	...	...	...	...	...	...

THERAPEUTIC USES. At the diverse stations where these waters are found the same diseases are treated as at the sodium chloride springs, but particularly certain rebellious skin diseases, manifestations of scrofula, and the graver forms of syphilis. They are more strongly indicated in scrofula than the waters that are richer in sodium chloride. Uriage is especially appropriate to this class of cases. The same resort, the most important among the French stations, has also acquired a reputation in the treatment of the severer forms of syphilis.

Abroad syphilitic patients are generally sent to Aix-la-Chapelle, where they are also subjected to mercurial inunctions. All we have said concerning the use of sulphuretted waters in the treatment of syphilis also applies to the treatment by chloride sulphuretted waters, especially those of Aix-la-Chapelle.

Chloride Bicarbonated Waters. The chloride bicarbonated waters are represented by those in which the proportion of bicarbonate of sodium is equal to or greater than that of chloride of sodium. Durand-Fardel establishes also another group of bicarbonated chloride waters, but these do not, it seems to us, form a distinct class.

BICARBONATED CHLORIDE WATERS.

Names.	Chloride of sodium.	Chloride of magnesium.	Bicarbonate of sodium.	Sulphate of sodium.	Carbonic acid.	Temp.
Saint Nectaire, Parc	2.544	...	2.127	0.168	0.683	19° C.
S. intermitt	2.062	...	1.723	0.133	0.477	45
Royat, Eugénie	1.728	...	1.349	...	...	35
Vic-le-Comte	2.000	...	2.900	0.200	...	16–34
Vic-sur-Cère	1.550	...	2.135	...	...	...
Ben-Laroun (Alger) . . .	...	...	...	...	...	...
Châtel-Guyon, Gubler . . .	1.552	1.583	2.250	...	...	...
			Bicarbonate of lime.		c.cm.	
Ems, Kesselbrunnen	1.030	...	1.980	...	553	48
Szczawnica (Gallicia), Magdalenenquelle	4.600	...	8.400	...	771	11
Vincenzbrunnen	2.900	...	4.200	...	1687	8
Gleichenberg (Styria), Constantinsquelle	1.800	...	3.500	...	1172	17
Selters (Nassau)	2.300	...	1.200	...	1139	31

The chloride bicarbonate waters are in part cold, in part warm; at some stations both varieties are present at the same time. The majority are rendered gaseous by the presence of a more or less considerable proportion of carbon dioxide. They differ sharply by reason of their composition from the pure chloride of sodium and the pure bicarbonate of sodium waters. Their uses are likewise different.

The French springs are characterized by a moderate mineralization, of sufficient strength, however, to endow them with well-marked properties. They contain scarcely more than 5 grammes of fixed principles, sometimes even less. Among them Châtel-Guyon occupies a special place, first, on account of its richness in chloride, divided equally between sodium and potassium chloride. Secondly, on account of the fact that the bicarbonate of sodium is replaced by the bicarbonate of lime. La Bourboule should also be named; it is likewise a chloride bicarbonate water, but the presence of a large proportion of arsenic is its chief characteristic.

Several of the foreign waters, as those of Ems and Selters, resemble those of France in the moderate amount of minerals they contain. There are others, however, notably those of Szczawnica, in Gallicia, which contain more than 8 grammes of sodium bicarbonate.

Physiological Effects. These waters are characterized chiefly by their action on the digestive tract, but they also exert an influence upon general nutrition.

Upon the digestive tract the action is essentially one of stimulation, as we have had the opportunity of observing in patients taking these waters, especially those of Saint Nectaire. This action renders the waters appropriate to the treatment of chronic gastropathies, characterized by a manifest hypopeptic state. The results produced must be ascribed, we think, to the combined effects of the small doses of bicarbonate and chloride of sodium.

The effects upon general nutrition have been but imperfectly investigated; we know of no physiological experiments with these waters. The clinical facts which we have observed indicate that the waters of Saint Nectaire increased the excretion of nitrogen.

The waters are also said to possess the power of influencing the bronchial secretion, an effect probably dependent upon the sodium bicarbonate.

Therapeutic Uses. The diseases for which the chloride bicarbonated waters are suitable are certain affections of the gastro-intestinal tract, various disturbances of general nutrition, and a few morbid conditions of the mucous membranes.

In France the chronic dyspepsias of the minus-hydrochloric-acid type are with advantage sent to Saint Nectaire, the waters of which have at the same time a beneficial influence upon the general nutrition. This resort has also acquired a reputation in the treatment

of albuminuria, which, as is well known, may have its origin in digestive disturbances. We believe that the waters of Saint Nectaire are of signal value in the albuminuria of chronic interstitial nephritis.

In cases of pronounced constipation the preference should be given to Châtel-Guyon. These waters are transportable, as are also those of Vic-sur-Cère and Vic-le-Comte.

Scrofula, in its lighter forms, is benefited by these waters; likewise the dermatoses, particularly certain forms of eczema.

For chronic inflammations of the bronchial mucous membrane, and even for tuberculosis, Royat and Ems are the resorts most highly recommended. Chronic uterine affections are also treated there.

Mixed Sulphates. While the pure sulphates are almost without exception used only for export, being in the proper sense not mineral waters at all, the second class of sulphates, the mixed sulphates, comprises an interesting series of waters, which have all the characters of true mineral waters. It is convenient to place in this group all the waters in which other active principles besides sulphates are found. Sodium bicarbonate and sodium bichloride are the most important of these constituents. The composition of these waters is, as a rule, very complex. In addition to the agents mentioned, we also find bicarbonate of lime, of magnesium, and of potassium, sulphate of lime and of iron, carbon dioxide, and nitrogen. These are the so-called polymetallic waters. They generally issue from volcanic rocks and traverse deposits of marl and gypsum. The majority are cold. They are rare in France, the most important being found in Austria.

MIXED SULPHATE OF SODIUM WATERS.

Names.	Sulphate of sodium.	Bicarbonate of sodium.	Carbonate of lime.	Sulphate of lime.	Chloride of sodium.	CO_2.	Temp.
						c.cm.	
Brides (Savoy)	1.16	...	...	1.71	1.83	...	34.5°C.
Santenay (Côte-d'Or), s. lithium	2.01	...	0.3	0.89	5.63	...	19
Carlsbad, Mühlbrunnen	2.30	2.00	...	...	1.00	180	57
Sprudel	2.30	1.90	...	...	1.00	104	73
Tarasp (Switzerland), Bonifacienquelle	2.20	0.90	...	...	...	1263	6
Luciusquelle	2.10	3.40	1.5	...	3.60	1112	6
Marienbad (Bohemia), Ferdinands	5.00	1.28	...	...	2.00	1527	9
Kreuzbrunnen	4.90	1.68	...	...	1.70	552	11.8
Franzensbad, Wiesenquelle	3.30	1.20	...	...	1.21	1200	10
Bohêmia, Salzquelle	2.80	1.10	...	...	1.14	840	11
Elster (Saxony), Salzquelle	5.20	1.60	...	...	0.80	980	9
Roohitsch (Styria), Tempelbrunnen	2.00	1.00	...	...	0.10	1129	10

The mixed sulphate waters are excellent medicinal agents, but have not been sufficiently studied. The association of sodium sulphate with the bicarbonate and the chloride of sodium, which characterizes some of these springs, notably that most important one of all, namely Carlsbad, constitutes a combination that is capable of influencing very markedly the processes of gastric digestion.

In small doses these waters stimulate the secretion, and probably also the movements of the stomach. Large doses, or the prolonged use of moderate doses, depress the gastric functions and may lead to the development of a state of apepsia.

The warm waters of these groups also engender an increased secretion of bile.

Very little is known of the effects which these waters determine upon general nutrition. According to Fulzer, they produce a diminution in the excretion of phosphoric acid, sulphuric acid, magnesia, and the chlorides. Seegen, on the other hand, explains in part the therapeutic action of the waters by stating that they increase the oxidation of the hydrocarbons, a theory that has not, so far as we know, been substantiated by experiment.

From the observations that have been recorded we infer that the mixed sulphate waters in their therapeutic properties resemble the strong bicarbonate waters, and are particularly useful in cases presenting an increase in urea and urates in the urine. Those waters in which the proportion of sodium chloride is high, as in the lithium spring of Santenay, have probably a slightly different action from those in which the quantity of that salt does not exceed two parts in a thousand.

Therapeutic Uses. The mixed sulphate waters are employed in diseases of the digestive tract and of the liver, as well as in affections characterized by disturbances of general nutrition.

The sufferers from gastric affections are sent chiefly to Carlsbad and to Marienbad. The only resorts in France that can approach these are Brides and Miers. The waters of Brides-les-Bains are easily digested; they purge in doses of five to six glasses, and rival chiefly those of Marienbad.

The water of Miers is a pure sulphate, but too feeble to figure among the purgative waters. It is a true mineral water, useful in gastralgic affections, and deserving more extended study.

The liver diseases amenable to the treatment by mixed sulphate

waters are those associated with biliary lithiasis. In this condition Carlsbad is *facile princeps.*

The intimate relations existing between chronic affections of the stomach and of the intestine and those of the liver enable us to understand why these waters are beneficial in both classes of diseases, and, indeed, the sulphates succeed best in chronic engorgements of the liver (chronic congestion, cirrhosis, etc.) secondary to chronic gastritis and enteritis. The good effects achieved in biliary lithiasis are more difficult of explanation. They are often very remarkable, and may go so far as to lead to the evacuation of the calculi almost without pain. Whether this is the result of a simple increase in the biliary secretion, or of a change in the character of the bile, or of a reflex action, we do not know.

It is difficult to give a positive answer. The antiphlogistic action of the treatment appears to play a part in some cases in the production of the therapeutic effect. The removal of duodenal and hepatic congestion, the suppleness of the bile-passages, and the increased fluidity of the bile are all active factors in the expulsion of calculi.

The waters under consideration are also employed in diabetes and in obesity.

Carlsbad is most popular among German sufferers from the former disease, and rivals Vichy; but the results obtained are somewhat doubtful, for Külz, Kratschmer, Kretschy, Riess, and P. Guttmann did not observe any diminution in the sugar in the urine; in some cases the treatment even aggravated the disease.

Since the waters of Carlsbad have a more pronounced influence upon the functions of the digestive tract, particularly of the stomach, than the strong sodium bicarbonate waters, their use should never be counselled without having first ascertained the condition of the gastro-intestinal tube, whether the patient complains of indigestion or not. This precept holds good for all cases of diabetes and obesity.

The sulphate waters of Bohemia are, in a sense, specialized; they attract the majority of obese patients, and everything—the regimen, dietetic and hygienic, and the methods of application—conduces to a reduction in the bodily fat. This reducing treatment is carried out especially at Marienbad.

As obesity has not a uniform cause, it is unwise to prescribe the reduction treatment indiscriminately to all cases.

In recent years the effort has been made to set up Brides as a rival

resort of those of Bohemia. It is possible to obtain at Brides therapeutic results, but we must not conceal the fact that almost no exhaustive studies have been made upon all these waters, the mineralization of which is both high and powerful. With the exception of a few researches on the influence of the Carlsbad waters upon the functions of the stomach, the whole question of the physiological action of the mixed sulphate waters remains obscure.

These waters are also employed in the treatment of paludal cachexia and of certain neuropathic states. The chronic engorgement of the spleen of malarial origin is relieved by the waters of Carlsbad or Marienbad; while the neuropathic conditions, particularly those depending upon uterine diseases, are benefited by the treatment at Franzenbad, the effect of which is both tonic and sedative

Before concluding it is proper to refer briefly to a few groups of waters which without constituting separate classes differ sufficiently from those previously considered to warrant their special mention.

Arsenical Waters. The arsenical waters, although considered a distinct class by some hydrologists, notably by Le Bret, do not constitute such a natural group as the chalybeate waters. They are few in number and very complex in composition. The most remarkable of the group is La Bourboule, which, by reason of the large quantity of arsenate of sodium that it contains (0.028, corresponding to 0.007 of arsenic), stands apart from other springs. It is rich in bicarbonate and chloride of sodium, and in that respect resembles Saint Nectaire and Royat. Cransac is next to La Bourboule, containing 0.009 of sulphide of arsenic, representing 0.0063 of arsenic. We should also mention Hammam-Meskoutine, in Algiers, with from 0.0025 to 0.005 of arsenate of sodium; la Dominique of Vals, Bussang, and Bouquet (Vichy). The waters of Plombières and Mont-Dore are too feebly mineralized to rank in this group. A number of arsenical waters are found abroad, the richest being the chalybeate sulphate waters of Roncegno and of Levico, in the Tyrol. The first contain nearly 0.10 of arseniate of sodium; the second from 0.09 to 0.80 of arsenious acid.

The water of Court-Saint-Étienne, in Belgium, contains about 0.0097 of arseniate of sodium.

The arsenical waters are reputed to possess the same therapeutic properties as the pharmaceutical preparations of arsenic. This is a theoretical view, and is not in accord with the results of the researches of Danjoy. The latter showed that the waters of La Bourboule,

administered in large doses, did not produce the toxic effects following the use of equivalent doses of arsenic. In reality, the composition of these waters is so complex that every station possesses its peculiar and distinctive properties.

At La Bourboule a large number of morbid conditions is treated, in some of which the administration of arsenic is certainly indicated. The usefulness of the waters of this resort is, however, very extensive, and depends, in part at least, upon other principles, and upon the temperature, which rises to 60°. At La Bourboule all forms of scrofula are treated, but the results are due rather to the sodium chloride than to the arsenic. Of dermatoses, the dry forms of eczema and psoriasis are especially benefited.

Among the diseases of the respiratory tract asthma, both the dry and the moist, is favorably influenced by the waters of La Bourboule. They are also of great value in disturbances of the hæmatopoietic apparatus, in the grave anæmias, and in Hodgkin's disease. Lastly, they are also employed in the treatment of diabetes.

Nitrogenized Waters. Nitrogenized waters comprise those which serve for the inhalation of nitrogen, described in a previous chapter. They are very feebly mineralized. In the absence of precise knowledge of the *rôle* of nitrogen it is premature to establish a class of nitrogenized waters, the existence of which seems at the present time to be admitted only by Spanish authors.

Iodo-bromide Waters. The iodo-bromide waters might be grouped with sodium chloride. Yet if this were done, it would be necessary to place apart certain waters, which are free from sodium chloride, but contain, in a total of 0.948 of fixed principles, 0.11 iodide of calcium and of magnesium (0.00937 of iodine), and 0.04 of bromide of calcium and of magnesium (0.0824 of bromide).

Evidently it is scarcely possible to establish a special class with this as the single member. The Saxon water, which is largely exported, is employed in tuberculosis and in certain skin diseases.

Lithia Waters. The lithia waters comprise a rather large class of waters, having a variable composition and belonging to different groups. Lithium was discovered by Truchot in some of the waters of Auvergne, especially in that of Royat. As this base plays an important part in the treatment of gravel and of gout, and, in general, in all the pathological states depending upon uricæmia, various hydrologists have attributed to it a large share in the results obtained in certain stations.

The following list is in part abstracted from the table of Truchot and Fredet.

ESTIMATION OF CHLORIDE OF LITHIUM.

	Milligrammes.
Santenay (s. lithium)	111
Royat (Saint Mart)	35
Châteauneuf	35
Les Roches	33
Saint Alyre	31
Médagne, eau de l'Ours	30
Châtel-Guyon	28
Saint Nectaire	22
La Bourboule	18
Mont Dore	8
Salzschlirf (Hesse)	160 (chlor.)
Salvatoi (Hongrie)	80 "
Quelques sources de Baden-Baden	30 "
Klausen et Szliacs	38 (carbon)

[AMERICAN MINERAL WATERS.

There is no country in the world which possesses as many mineral springs as do the United States, nor does any other region possess so varied an assortment. It is estimated that there are more than four hundred springs for which active medicinal power has been claimed, but of this total only a few, comparatively speaking, have been generally recognized by the public or the profession. It is hardly necessary to add that the therapeutic measures employed in the application of these waters are practically identical, at least in general principles, with those of the European resorts.

While the mineral springs of the United States are numerous they are by no means equally distributed, certain regions having a large number while others have none. Many of them are to be found in close relation with the Appalachian Mountains in New York, Pennsylvania, and particularly in the Virginias.

The mineral springs of Maine belong to the so-called alkaline, saline, and chalybeate waters, the last largely predominating. Some are sulphuretted and a few contain carbonic acid gas, but no thermal springs are found in this State, the average temperature varying from 40° to 46° F. It is also worthy of notice that very few of the springs of Maine contain large amounts of mineral matters, nearly all of them being chemically indifferent. In New Hampshire the springs supposed to possess medicinal activity are not numerous, and, like those of Maine, contain small quantities of mineral water. In Vermont only a small number exist, and of those sulphuretted

springs are most abundant. There are no springs of any great importance in the State of Massachusetts, the most noteworthy perhaps being the Berkshire Soda Springs. One moderately thermal spring is found in Williamstown. There are no medicinal springs in Rhode Island, and those in Connecticut are of very little if any importance, owing to their feeble amounts of mineral. Most of them are chalybeate and very feebly sulphuretted. In New York there is a larger number of mineral springs than in almost any other State in the Union; and not only is this true, but the springs are of very great variety: many of them are sulphuretted, still others contain large amounts of mineral ingredients, such as salines and chalybeates, but there is no spring, so far as we know, which has a temperature above 75°. The most noteworthy sulphuric acid springs in the United States are found in New York. In New Jersey there are practically no springs of any medicinal value. In Pennsylvania the most noteworthy springs contain iron, alum, and magnesium. The springs of Delaware and Maryland are not worthy of note, but the springs of Virginia are numerous and strongly mineralized. These springs are chalybeate or sulphuretted as a rule, as are also those of West Virginia, these two States containing an equal number of springs, practically, with the State of New York. The springs of North Carolina are also chiefly sulphuretted and chalybeate waters, but none of them are of very great importance. This is also true of South Carolina, Georgia, and Florida. Alabama contains few mineral springs, and these are most of them chalybeate or sulphuretted; very few are employed for medicinal purposes. This is also true of the springs found in Mississippi and Tennessee, although in the latter State they are much more numerous than in those just named. In Kentucky there is a large number of springs which are also of very considerable medicinal value, the most celebrated being the Blue Lick Water, which is sulpho-saline, and the Crab Orchard Springs. The springs of Arkansas are not worthy of note except the celebrated Hot Springs, which are of the greatest possible value in the conditions for which thermal hydrotherapy is indicated. The quantity of water which is discharged from these springs is practically unlimited, but the mineral ingredients which they contain have little to do with their efficiency. The springs of Louisiana and Texas have not been developed. In Ohio the springs are very numerous, but none of them are particularly efficacious. In Indiana the waters are mostly chalybeate or sulphuretted, and this is also

true of the mineral springs of Illinois. In Michigan saline and sulphuretted springs predominate, while in Wisconsin they consist chiefly of alkaline, chalybeate, and calcic waters. The mineral springs of Missouri are very numerous and of considerable variety. In some portions of this State there are strong salt springs which have been used for the preparation of ordinary salt.

There are no springs in America, so far as we know, which compare in strength or efficacy to the sulphate of magnesium and sodium springs of Europe. Those springs which contain these salts are used for the relief and cure of chronic constipation and the ailments associated with it, such as hepatic torpor, gastro-duodenal catarrh, and obesity. They are also sometimes employed for the relief of kidney complications by unloading the system of impurities through the bowels and by the diuretic power which they possess. They are drunk freely, to the extent of several pints a day, in many cases, the most marked purgative effect being obtained if they are taken freely before breakfast and with exercise; whereas, if they are taken at various times during the day, in small amounts, the purgative effect is lessened and the diuretic effect is increased.

Sulphur springs contain in addition to sulphuretted hydrogen, sulphate of lime and bicarbonate of magnesium in large quantity, with free sulphur, which is formed by the action of the oxygen of the air upon the gas, thereby producing the milky turbidity of the water (White Sulphur Springs). In Canada the Sandwich Spring and Charlottesville Spring contain remarkable amounts of sulphuretted hydrogen. The sulphur springs are much resorted to by persons suffering from obstinate catarrh of the gastro-intestinal tract, and are, without doubt, most efficient in many cases. Even in catarrhal states of the respiratory and genito-urinary tract they are of value, and are employed by drinking, bathing, and atomization.

The saline waters are employed in the treatment of gout, rheumatism, and the uric acid diathesis in general and whenever an active diuretic water is needed. The types of the springs supplying such waters in America are to be found at St. Catharine's in Canada (a chloride of sodium spring), which is one of the strongest springs in the world, its total salts amounting to 450 grains to the pint; and at Saratoga in the Kissingen and Vichy.

Chalybeate springs are found at various places and often strongly impregnated with alum or sulphuric acid in addition to the iron which they contain. They are useful in cases of anæmia and debility,

and when containing alum are peculiarly efficient when diarrhœa complicates the case.

The springs of the United States which are used for laxative and purgative properties depend upon numerous mineral ingredients. As has already been stated, there are no springs of great prominence in the United States that depend for their influence chiefly upon the presence of sulphate of magnesium and sodium in the sense that many of the foreign waters depend upon these ingredients. There are many laxative waters, however, the most celebrated being those of Saratoga.

There still remain two classes of waters to be considered, namely, those which depend for their activity upon the heat which they contain, and those which act by virtue of their purity and so wash out of the body many impurities by dissolving effete materials and flushing the kidneys.

The thermal springs of the United States are used chiefly in the treatment of syphilis and skin diseases and for the relief of rheumatic affections. They are found in many places, but those most worthy of note are at Hot Springs, Arkansas; Glenwood Springs, Colorado, and Hot Springs, South Dakota. Those at the former place have a temperature of from 90° to 150° F., and both here and at Glenwood Springs there are ample bathing facilities and other means of obtaining the results sought after in similar resorts in Europe.

The pure water springs of this country are used to flush the kidneys and dissolve effete materials in the system.

It is manifestly impossible to name or give the analysis of all American springs, but a number of the better known may be mentioned.

The springs containing the largest amounts of Epsom and Glauber's salts are the Crab Orchard Springs, of Lincoln County, Kentucky, which are not only used at their point of origin, but also employed in concentrated form in many parts of the country. An analysis shows them to contain, as the chief ingredients, from 20 to 26 grains to the gallon of magnesium sulphate, from 2 to 7 grains to the gallon of sodium sulphate, and from 3 to 7 grains to the gallon of carbonate of lime. The Magnesium Springs at Bedford, Pennsylvania, contain 39 grains per gallon of sulphate of magnesium, 100 grains of sulphate of calcium, and 10 grains of carbonate of calcium as their most prominent ingredients. Spring No. 1 at Oak Orchard, New York, contains 35 grains of sulphate of magnesium and 75 grains of sulphate of calcium to the gallon, but in addition contains alum,

iron, and sulphuric acid in very large amounts, so that it ought not to be classed as a purely purgative spring.

The saline purgative waters not depending upon sulphate of magnesium or sodium are very numerous, and because of their composition possess considerable diuretic power in many instances. They are typified by the Saratoga waters, which arise from about thirty springs, several of which greatly exceed the others in medicinal activity and size. The principal springs are the Champion, Congress, Hathorn, Carlsbad, and High Rock Springs. The Champion Spring contains as its most active ingredients 702.24 grains of sodium chloride to the gallon, 227.7 grains of calcium bicarbonate per gallon, and 193.91 grains of magnesium carbonate per gallon, the other ingredients being present in such small quantities as to be unworthy of notice. The Congress Spring contains 334.4 grains of sodium chloride per gallon, being therefore a much weaker spring in this salt than the Champion. The Hathorn Spring occupies a mediate position between these two. It contains 509.97 grains per gallon of sodium chloride, 170.65 grains per gallon of calcium bicarbonate, and 176.46 grains per gallon of magnesium bicarbonate. The High Rock Spring contains 390.13 grains per gallon of sodium chloride, 131.74 grains per gallon of calcium bicarbonate, and 54.92 grains per gallon of magnesium bicarbonate. One of the most interesting of these springs is the so-called Geyser Spring, which contains a large amount of carbonic acid gas, and which spouts with very considerable force. It contains 562.8 grains of sodium chloride to the gallon.

The method of drinking Saratoga water varies to some extent with the spring which is used and the individual case, but the general rule when a cathartic effect is desired is to drink two or three glasses leisurely early in the morning, then to take a brief walk, followed by another glass of water, and half an hour later to take breakfast. Should an alterative influence be desired, a glass of the water is taken once, twice, or thrice a day. Should the patient suffer from catarrhal conditions or febrile movement, care must be taken that the waters of the Columbian, Pavilion, and other of the Saratoga Springs containing iron in considerable quantity should be avoided.

The following table from Irwin's *Hydrotherapy at Saratoga* gives the relative strengths of the various springs.

It will be noted that all these springs contain carbonic acid gas, thereby rendering their taste agreeable. The Kissengen and Vichy are less laxative than the Champion, Congress, and Hathorn.

Skeleton Analysis of One U. S. Gallon.

Name of Spring.	Total solids.	Total chloride.	Total alkaline bicarbonates.	Iron.	Lithia.	Carbonic acid gas. Cub. in.
Carlsbad	1121	715	400	0.70	6.70	713
Champion	1195	742	446	0.65	6.25	465
Columbian	408	267	130	5.58	...	272
Congress	894	577	306	0.74	5.33	537
Empire	680	510	163	0.80	2.09	644
Eureka	258	166	79	3.00	...	239
Excelsior	514	377	124	3.22	...	250
Favorite	719	454	258	0.47	5.32	963
Geyser	991	586	400	0.98	9.01	454
Hamilton	460	297	154	5.39	...	316
Hathorn	821	512	305	0.86	7.30	491
High Rock	628	399	221	1.48	...	409
Imperial	270	127	140	0.10	3.24	287
Kissengen	351	152	193	1.56	5.13	361
Lafayette	1290	818	463	0.76	8.05	810
Patterson	518	281	233	1.22	2.32	417
Pavilion	687	467	210	2.58	9.49	332
Peerless	419	201	212	1.03	1.29	502
Putnam	416	213	197	1.08	1.97	405
Red Spring	255	90	159	2.10	0.94	...
Royal	518	274	236	1.23	2.24	500
Saratoga A	657	565	85	1.72	...	212
Seltzer	302	135	160	1.71	0.90	324
Star	337	145	186	2.51	2.04	407
Union	696	462	228	0.27	2.00	384
United States	331	150	176	...	4.85	245
Washington	350	182	158	3.81	...	363
Vichy	367	142	222	0.06	1.77	383

At Ballston, New York, there are no less than six springs which may be employed, one of which contains iron. The chief mineral ingredients are: sodium chloride, from 400 to 750 grains per gallon; calcium bicarbonate, from 170 to 240 grains per gallon; sodium bicarbonate, from 11 to 95 grains per gallon; and lithium from 6.75 to 7.75 grains per gallon. The waters at Ballston are used for practically identical purposes with those at Saratoga.

Of the chloride of sodium waters, the most powerful, as we have already stated, is that of St. Catherine's, in Canada, which is most commonly employed for purposes of bathing in the treatment of rheumatism, gout, and scrofula. Nearly every means of employing water in therapeutic measures are obtainable at this resort.

The sulphur waters may be represented by the Greenbrier White Sulphur Springs of West Virginia, which contain as their chief active ingredients from 70 to 80 grains per gallon of calcium sulphate and from 20 to 35 grains per gallon of magnesium sulphate, in addition to sulphuretted hydrogen in considerable quantity, and are used for their purgative and alterative influence. They also possess some diuretic power. Other springs of a similar character are the well-known Sharon Springs in Schoharie County, N. Y., which contain

calcium sulphate from 76 to 85 grains to the gallon, and sulphate of magnesium from 18 to 22 grains to the gallon, in addition to considerable quantities of sulphuretted hydrogen. They are used for practically identical purposes as the Greenbrier Spring, although, when a cathartic effect is desired, other more powerful purgatives must be associated with them. Other sulphur springs of considerable importance are found at Richfield, Otsego County, N. Y. One of them is the White Sulphur Spring, which contains large quantities of sulphuretted hydrogen (nearly 15 cubic inches to the gallon), and as its next most prominent ingredient about 112 grains to the gallon of calcium sulphate. Another of the springs at Richfield contains still more sulphuretted hydrogen, namely, 24 cubic inches to the gallon, but only small amounts of other mineral ingredients.

In iron, alum, and sulphuric acid springs the United States excels Europe, the most notable being found at Oak Orchard, New York; Rockbridge Alum, in Virginia, and Bedford Alum, in Virginia. The iron generally occurs in association with alumina, as in the Rockbridge water, or with sulphuric acid, as in the Oak Orchard acid water. These waters are particularly useful in cases of chronic diarrhœa, with anæmia, especially of the chlorotic type. Analysis of the Rockbridge water, which is derived from springs Nos. 2 and 4, shows the presence of 42 to 72 grains of alumina to the gallon, while the iron varies from a trace to nearly 5 grains to the gallon, and the sulphuric acid from a trace to 15 grains to the gallon. According to Mallet's analysis, the proportion of sulphate of alumina in the gallon of spring No. 7 at Rockbridge equals over 81 grains, the sulphuric acid nearly 5 grains, and the iron nearly 6 grains. The dose of these waters is about half a glass several times a day. The Oak Orchard acid water contains extraordinary amounts of sulphuric acid, in some springs amounting to 135 grains to the gallon, in association with large amounts of iron, as much as 32 grains to the gallon. Not more than two or three wineglasses of this water should be taken in a day.

There still remains a large number of waters which possess distinct diuretic properties, largely depending upon their purity for their activity. They are chiefly useful in the uric acid diathesis. Chief among these should be mentioned most of the so-called lithia waters, many of which contain lithia in very small quantities in many instances. The most valuable of these pure domestic waters is probably the Poland, of Maine, and the Londonderry Lithia Water of

New Hampshire. There are two springs at Poland, one of which contains only 3.95 grains per gallon of solids in the gallon. The other contains as its chief medicinal ingredient chloride of sodium in the proportion of 4.85 grains per gallon, carbonate of iron 2.24, calcium carbonate 2.33, and potassium sulphate 0.90; altogether the proportion of solids equals 14.29 grains per gallon. The Londonderry Water contains about 12 grains of calcium sulphate and 7 grains of lithium bicarbonate to the gallon, according to Satterlee.

Still other springs of this class of pure waters possessing diuretic properties are the Capon Springs of Hampshire County, West Virginia. The springs here are known as the Main and Beauty Springs. The first contains as its principal ingredients calcium carbonate in the proportion of 8.33 grains to the gallon, sodium carbonate 0.59, calcium sulphate and silica 0.70, and 1.44 of magnesium carbonate. The second, or Beauty Spring, has 8.36 of calcium carbonate, 0.63 of sodium carbonate, 1.27 of magnesium carbonate, and 0.67 of silica. The water is also highly charged with carbonic acid gas, has little or no taste, and possesses a natural temperature of about 66°.

Another spring of this class is the Bethesda Spring at Waukesha, Wis., which contains calcium bicarbonate, 17.2 grains per gallon, and magnesium bicarbonate 12.39 grains per gallon, as its chief ingredients.—Ed.]

Conclusion. We shall conclude this rapid survey of mineral waters by a few general considerations on the importance of the treatment by these agents.

This treatment by the complexity of its component elements is capable of producing profound and lasting modifications of general nutrition.

The success of the therapeutic effect renders the choice of a suitable place a problem of great gravity, for we must not forget that an error may entail deplorable consequences.

In order to choose wisely the following are indispensable data: a thorough knowledge of the patient, a precise diagnosis, and a clear conception of the value of the different resorts.

In studying the patient great care should be taken to ascertain the state of general nutrition and that of the digestive tract, as well as the power and character of the reaction of the patient's nervous system.

These are the three most important suggestions from the practical standpoint that have found place in this volume.

As regards the stations the choice is great, and more could be named than those already mentioned. In our opinion, it is far better to acquire a thorough knowledge of the principal resorts than to burden the mind with the entire list of mineral waters. There is a great advantage in a sojourn at a station of the first rank, of which the effects are best where the arrangements are the best, and where the patients can find comfort, diversion, and, above all, competent medical advice.

It is important to consider earnestly the specialization of each station. While, considered alone, it appears that every resort is applicable to a great variety of diverse conditions, it is none the less true that in reality it is superior only in a restricted number of cases; sometimes it is especially appropriate to a certain form or developmental phase of a chronic disease. In rheumatism, in gout, and in scrofula and tuberculosis the cures vary with the different epochs of the evolution of these diseases.

After the choice of a resort has been made the direction which the "cure" is to assume must be decided.

Unquestionably the mode of administration of the waters and, in general, the conduct of the treatment are of the greatest importance in the results obtained. The same waters, according to the manner in which they are administered, *intra et extra*, are capable of determining in the same individual very different results.

The physician who is consulted in regard to the selection of a watering-place will be able to indicate the character of the effects desired; but the immediate direction of the treatment, the details in regard to choice of methods, doses, etc., concern solely the physician of the station, whose supervision is always indispensable.

PART VI.

ELECTRICITY.

In electro-therapeutics, as in every other branch of therapeutics, our knowledge of empirical facts has always been in advance of scientific explanation, and to-day, in spite of the progress that has been made in physics, only a partial explanation can be given of the facts observed in electro-physiology and electro-therapy.

We must, nevertheless, take account of these facts, even if they are not perfectly understood. We have, in fact, reached a sort of transition period. Electricity is better defined mathematically and physically than it used to be. Our armamentarium, or the instruments which we use in electro-physiology and in electro-therapeutics, has been much improved, and thus we are enabled to state more and more precisely the conditions under which the reactions of the organism are manifested in response to electrical excitation.

But, on the other hand, the complexity of the subject is such that, in spite of this improvement, the different problems of pure physics have not yet been perfectly solved, and consequently the laws governing organic reactions cannot be expressed as definitely as we should desire.

This state of things, however, does not deter us from the study of electrization ; but, on the contrary, if possible, increases the interest of the subject. The physician, in fact, is accustomed, even more than is the man who studies pure science, to take account of empirically observed facts. The situation will merely oblige us to reserve our judgment with regard to certain explanations, which may be considered as still rather premature, of the complex phenomena developed by the application of electricity to man.

We shall therefore consider electricity solely from the point of view of a practitioner of medicine, and simply cite those facts which shall be sufficient to enable us to make a judicious use of one of the most remarkable of therapeutic agents.

The tendency at present, especially in large cities, is to leave the application of this agent to specialists, who naturally are better acquainted with the management of the various forms of apparatus. While not condemning this practice, which has certain advantages, it is to be remembered that it is not necessary to be a professional electrician in order to apply, properly and usefully, the different methods of electrization. It is necessary for practitioners in small cities and in the country to be able to put these methods into practice, and their patients ought not to be deprived of the resources which such methods frequently offer, and which are sometimes of considerable importance.

Confining ourselves to the field of therapeutics, the facts that we discuss will relate mainly to electro-dynamics and electro-therapeutics properly so-called. We shall not have to dip deeply into the difficult and rather special questions of electro-physics and electro-physiology, for the two branches before mentioned will suffice to give us all the facts that the practitioner needs, for the latter has to think of electricity as a sort of medicine, whose principal properties it is his business to be acquainted with. It is furthermore indispensable that he should know how to use a definite dosage, and one proportionate to the effects which he wishes to obtain.

We must know enough of electro-physics to understand the properties of electricity, and the proper apparatus for obtaining, regulating, and measuring this agent in its different forms.

Every modification of the characteristic properties of matter is produced by some immediate cause—that is, in the language of physicists, by some energy-change. If we study the subject carefully, we see that every force, or modifying influence, originates from the transference or transformation of some form of energy that was previously manifest. All these forms of energy are capable of transformation, one into the other, according to a mathematical law which we have already cited in speaking of thermic agents. Take, as an example, the heat derived from coal, which, when transformed through the agency of a steam engine, becomes the energy of mass-motion. This energy expended upon a dynamo-electric machine gives an electric current which, according to the bodies upon which it is made to act, is capable at will of producing motion, generating heat, light, and causing chemical combination or decomposition. Such transformations are daily realized and made use of in industry.

Before attempting to define electricity it will be found desirable to

give as clear an idea as possible of what is called the ether. We know matter by its properties, as perceived by means of our senses; in other words, the existence of any form of matter is to us only an inference from the phenomena to which it gives rise. By evidence of precisely similar nature we are led to believe in the existence of a medium called the *ether*, pervading all space and penetrating between the molecules of matter, which are imbedded in and surrounded by it as the earth is surrounded by its atmosphere. We cannot see, hear, feel, taste, smell, exhaust, weigh, or measure it, and yet all this, paradoxical as it may seem, furnishes absolutely no proof that it does not exist. Briefly stated, the proof of its existence is this: It furnishes the basis of the sole conceivable explanation of very many physical phenomena.

These phenomena occur just as they *would* occur if all space *were* filled with intangible and invisible mediums capable of transmitting motion and energy, and we can account for all these phenomena on no other hypothesis; hence our belief in the existence of the medium. The evidence of the existence of ether is as strong and direct as that of the existence of air. The eye is an ether sense-organ just as the ear may be called an air sense-organ. The ether transmits energy in the form of waves set up by the vibrations of molecules and atoms of ordinary matters. The small portion of ether energy capable of producing the sensation of sight we call *light*. That the medium surrounding a body charged with electricity plays an important part in the phenomena was shown by Franklin in 1748. It has since been shown in many ways that the various non-conducting mediums called *dielectrics* are really far more important than the conductors; and that when a body is charged with electricity the ether in the vicinity is in a strained state, the character of which depends on the conditions.

The idea that electricity is an incompressible fluid is found in the writings of Cavendish, but Maxwell by his investigations made the idea a part of scientific belief.

Lodge offers a provisional hypothesis that the ether consists "of electricity in a state of entanglement similar to that of water in a jelly." But later he says: "We now proceed a step further, and analyze the ether into two constituents—two equal and opposite constituents—each endowed with inertia, and each connected to the other by elastic ties; ties which the presence of gross matter in general weakens and in some cases dissolves. The two constituents

are called positive and negative electricity, respectively; and of these two electricities we imagine the ether to be composed."

We define electrification as a special condition of a body associated with or brought about by a separation of the ether constituents. In all cases of electrification, therefore, we may assume the electric ether to be in a strained condition, from which it tends to recover by reason of its very great elasticity.

The hypothesis of an ether and of the effect of its stress in producing the electric state allows us to use the term electric fluid, which is convenient for describing certain phenomena. We must not attach to this hypothesis more importance than it deserves, for a certain number of phenomena ill accord with it.

What it is important for us to keep in mind is that every body the electric state of which is not zero possesses potential energy, and that in this condition it is in a position to accomplish work.

Take, for instance, a battery furnishing a current of considerable intensity. In connection with the wire forming the external circuit is placed a fine platinum wire. When a current is passed through the circuit thus formed the platinum wire becomes heated and presently you will see that it becomes incandescent. The electric current has met with an obstacle, viz., the resistance of the fine wire; from this there results a transformation of energy at the point of obstruction. The energy of the current has been changed into heat and light in this case, while under other conditions the same energy will give rise to the phenomena of motion or of chemical action.

But whatever may be the theory as to the nature of electricity, the law of the conservation of energy is all that is requisite for the comprehension of electrogenesis; that is to say, of the various means of producing the electric state in bodies. These means are of three kinds—mechanical, chemical, and physical. Moreover, since the human organism is constantly the seat of physico-chemical phenomena, it must itself be considered as a source of electricity. From this fact arises the great complexity of the phenomena observed both in physiology and therapeutics when an electrified body is placed in relation with the organism.

All the sources of electricity are utilized in medicine. Let us briefly indicate the different kinds of apparatus based upon the different methods of producing the electric state.

In the first place, we may mention static machines, in which the electric state is obtained by mechanical action (friction), reinforced

frequently by a physical action known under the name of "influence."

In the second place, we employ varieties of apparatus giving rise by chemical action to a current (battery current), which is utilized either directly or after it has produced the physical effects denoted by the name of induction.

Finally, we employ varieties of apparatus which produce induction phenomena directly, and without the intervention of a chemical action—*i. e.*, do so by physical action (magneto-electrical apparatus).

Let us now consider, for the present, in a general way only, the characters of the electric states which these instruments produce. We will thus take a brief survey of the principal qualities of this remedy which are placed at our disposal. If we attempt to appreciate these qualities by some of the effects which they produce, we observe the following facts :

The static machines give rise to a wide diffusion of the fluid or by its discharge to effects having mainly a powerful mechanical action.

The galvanic or battery currents produce mainly chemical effects. Thus we can see how the current produced by two large Gaiffé elements steadily decomposes the water in a voltameter.

The induced currents have almost no chemical action, while they produce an intense mechanical action, which is clearly manifested in excitation of the nerves or muscles. Thus with an induction-machine we can excite energetic contraction in the leg of a frog by means of an agent which produces no effect upon the voltameter.

It would then seem at first sight as if electricity was capable of appearing in various disguises and of placing in our hands agents which are manifold and distinct from one another. This, however, is not true. The electric state is always the same as far as its nature is concerned, but it is marked by a certain number of physical properties, which, considered with respect to one another, are more or less predominant, according to the manner in which the electric state has been produced. In other words, the predominant properties of the electric state vary with the source of the electricity.

When we have recourse to mechanical action (friction), as in the static machines, the electricity spreads over the surface of bodies, and if they are good conductors it leaves them with extreme rapidity. Hence it is necessary to insulate these bodies upon which the electricity accumulates, and from which it tends all the time to escape. The dominant property in this case is *tension*.

When we make use of chemical action the electricity produced is started, as we may say, with but little energy; its transmission along the circuit is arrested by a comparatively slight resistance. But, on the other hand, chemical action develops a great quantity of electricity, which may become the origin of other chemical actions. The dominant property here is quantity.

In electric states which originate an induction the qualities are intermediate. We obtain by this means more quantity than when we employ mechanical action as our source of supply; but still the tension is by far the predominant property, even in this case.

Let us stop for a moment in a general consideration of this subject, to examine more particularly these terms *tension* and *quantity*, which it is of the greatest importance for us thoroughly to understood.

The word tension is no longer used in physics; the term *potential* is employed in its stead. To the physicist potential is a mathematical function defined by means of an integral. But this definition is abstruse; there is no reason why we should despair of forming a precise idea of what potential is.

Various comparisons can be of assistance to us in this regard. In the first place, we can grasp the idea of the difference between the terms quantity and potential by comparing a river with a slight, gradual fall to a torrent. The latter has a small delivery under a high pressure; the former, in spite of its great delivery, shows a low pressure. The pressure in this case gives you our first idea of potential.

Again, when we connect with each other two vessels full of water, but showing a difference of level in the two, this level is soon restored, whatsoever be the shape of the vessels; so, also, when two bodies of different potentials are connected with each other, a movement of positive electricity from one to the other is always produced.

Potential, then, is to electricity what difference of level is to hydrodynamics. It is evidently independent of mass or quantity. We may then speak of electric level or of potential.

If we take an electrified body and attach it by a long slender wire to a gold-leaf electrometer, the indication which the latter furnishes will be the same, whatever point of the electrified body is touched by the conductor, provided the conditions remain the same. This indication is independent of the amount of the charge at the point touched. It varies only with the electrical state in which the

body may be. Hence it serves to characterize a particular state of the body, a state which manifests itself by that something that we call potential.

Potential, in other words, marks this electrical state in the same way that the temperature marks the calorific state; and the electrometer serves to define potential numerically just as the thermometer defines the temperature.

We take as the zero the potential of the ground, although the electrical state of the latter may vary under certain influences. When above zero the value is said to be positive; when below zero, negative. Every potential is thus denoted by a number which is affected with the sign + or —. The scale is an arbitrary one, just as that of the thermometer is. Two bodies at the same potential are in a state of electrical equilibrium.

It is also possible to define potential in terms of work.

Lastly, it must be noted that electrical phenomena depend upon difference in potential. In reality, these differences take their origin from the electrogenic force—that is to say, the mechanical, physical, or chemical action which disturbs the state of electrical equilibrium, or, in other words, which combats the return of the electrified body to a state of equilibrium. This force is called *electromotive force.* Keeping up our comparison of electrical with hydrodynamic phenomena, we may say that this force is analogous to that which produces the rise of water in a pump, and, consequently, depends upon a difference in level or a hydraulic pressure.

The electromotive force depends essentially upon the nature of the action exerted upon bodies in order to break up their state of electrical equilibrium. In the case of chemical action it varies with the affinity of the bodies for one another, and, consequently, with the internal composition of the bodies present. It results from this that for a given metal and the same acid solution—that is, for the same chemical action—the electromotive force is invariable whatever is the amount of surface immersed in the liquid, or, in other words, whatever the quantity of electricity produced. So, too, the same stroke of the piston always determines the same difference in level of the liquid, although the quantity of the latter will vary according to the diameter of the body of the pump.

The current produced in a galvanic battery results from a difference in potential between the positive and the negative pole. Now if the positive potential is denoted by $+ e$ and the negative potential

by $-e$, the difference, $2e\ [= (+e) - (-e)]$, represents the electromotive force.

Quantity, electrically considered, represents a totally different quality from potential. It is proportional to the quantity of mechanical or chemical energy expended in order to set the electromotive force in action.

Having considered these premises, let us return to the subject of electrical apparatus; we shall now be prepared to understand better their special characters.

In an electrostatic machine the mechanical action which serves as the generator of electricity gives rise to a very high electromotive force, and since the electric fluid spreads with great ease over the collector, and the latter offers no resistance, we get from the electromotive force a maximum effect—*i. e.*, an electric state of high potential. The result of this is that violent mechanical effects are produced, in spite of the very slight quantity of electricity involved. Moreover, the machine can be discharged nearly instantaneously. For these reasons we call the static machines "tension apparatus."

Induced currents have analogous properties. They have a high electromotive force, but the quantity of electricity which these currents represent is very slight.

In the galvanic battery, on the contrary, the mechanical action gives rise to a weak electromotive force, and all the weaker, because, for reasons that we understand later, we try to make use of very weak chemical affinities in constructing the batteries. Consequently the current of a galvanic battery has a very low potential. But the chemical action develops a considerable quantity of electricity, the latter depending, not upon the energy of the electromotive force, but upon the quantity of the material consumed in the process. We may, therefore, compare the battery current to a stream of liquid flowing down a gentle slope.

When we use dynamo-electric machines, we find that they also furnish quantity currents, the quantity in this case depending upon the amount of mechanical energy expended.

If we interrupt the external circuit traversed by the battery current by separating the two ends of the wires by even the slightest distance, the flow of electricity is stopped at once; and, *per contra*, it is possible to draw sparks several centimetres in length from a static machine which is incapable of decomposing a single particle of water.

Induction machines manifest properties analogous to those of the

static machines. For example, a Ruhmkorff coil can generate sparks of some length without being able to accomplish any chemical work appreciable by the voltameter.

This rapid review of the properties of the apparatus which we have at our disposal shows us that the galvanic battery is a vast reservoir with a low pressure, and that the electrostatic machine is a reservoir of little capacity, but of high pressure. The electrical phenomena with which we have to deal depend upon these different conditions under which the electric current may be manifested.

In order to make the reader understand the use that we make of these different varieties of apparatus, we must supplement the facts that we have already acquired by some ideas with regard to *resistance.*

When we make use of the galvanic current, the intensity of the work obtained depends, not only upon the factors already examined (tension, quantity), but also upon the resistance that has to be overcome.

A comparison, which we shall borrow from Niaudet, enables us to grasp readily what is meant in electrophysics by the term resistance. Let us imagine the case of a windmill. Here there are two mechanical elements present: on the one hand, the motor force, or wind pressure; on the other, the resistance involved in the work done. In this sort of machine there are two causes of resistance. The first is represented by the useful work (the grinding of the mill); the second results from the mutual friction of the parts of the machine set in motion. This latter sort of resistance is called passive.

We shall find the same factors in the galvanic battery. An electromotor force is generated in the battery; the energy produced is used up in overcoming passive resistance and in doing useful work, varying according to the manner in which the current is applied. The passive resistances are those which the current encounters in its passage through different parts of the circuit. When the latter is continuous with itself, or when the current is not made to pass through any form of apparatus adapted for doing work, there are no resistances, except those of the passive kind, which include the resistance in the external circuit and the internal resistance of the battery.

To these various data we must add one more, that of *intensity.* By the term intensity of a galvanic current is meant the quantity of electricity passing through a conductor in one unit of time, *i. e.*, in one second.

Owing to the determination of what are called the electrical units,

the different factors which we have just reviewed can be expressed by values, in regard to which there is now a universal agreement. Electricity is thus a remedy which has become easy to measure the dose of.

The work of agreeing upon the electrical units, begun by the British Association for the Advancement of Science, was completed in the year 1881 by the Congress of Electricians which met at the Paris Exposition. These units have been chosen in such a way as to facilitate calculations, based upon the law of the conservation of energy. They are derived from what is called the C. G. S. (centimetre-gramme-second) system. It is indispensable that the physician should become familiar with the following units, at least:

The *unit of electromotive force*, known under the name of the *volt* (from Volta), is nearly equal to the electromotive force in a Daniell's cell. In batteries used in medicine, the electromotive force varies from about 0.9 to 15 volts.

The *unit of resistance*, or *ohm* (from the name of the physicist Ohm), represents the resistance offered by about 100 metres of telegraph wire, 4 millimetres in diameter, or by a column of mercury having a section of 1 square millimetre, and a length of about 106 centimetres (about 1 metre).

The *unit of intensity*, which formerly bore the name of Weber, is now called the ampère (from the name of the French physicist). The ampère is the intensity of a current furnished by an electromotive force of one volt acting against a resistance of one ohm; so that the unit of intensity corresponds to the unit of electromotive force and the unit of resistance. A current of one ampère being extremely strong, we reckon in electro-physiology and in electro-therapy by thousandths of an ampère. The thousandth of an ampère (milliampère) is, then, as far as we are concerned, the true unit of intensity.

To this list I will add some units, which practitioners have less use for, but which are employed all the time in electro-physiological research.

The *unit of quantity*, or *coulomb*, is the quantity of electricity delivered by one ampère in one second. Thus one coulomb per second represents a current of one ampère.

The *unit of capacity*, or *farad* (from Faraday), is the capacity of a condenser, which, when there is a difference of potential between its

terminus of one volt, receives a charge of one coulomb. In physiology we reckon by microfarads.

The *unity of work*, or *joule*, is of equal interest. In dynamics, work is reckoned in *ergs*. The erg is the work produced by the unit of force, or the dyne, when the point of application of the latter is displaced through one centimetre. The joule is the amount of work represented by the product of 1 volt by 1 coulomb; it is equal to 10^7 ergs, or about $\frac{1}{10}$ of a kilogramme-metre.

Power or activity is defined as the rate of doing work. If we take the time into consideration, we get the idea represented by the *watt*, or *unit of power*, or *activity*. The watt corresponds to the activity when work is done at the rate of one joule per second. If it has not been possible for the reader to grasp all these preliminary, purely physical facts, he need not be alarmed, for we shall return to the more important of them later, and study them more in detail.

We are now about to become acquainted with the principal forms of electrical apparatus, and you will recall the physical principles upon which they are constructed.

Static Electricity. *Static electrization* represents the method that was the earliest known and made use of. After having been given up for some time, it has come into favor again. This renewal of favor seems really to be based upon sufficient proofs of its utility.

In medical machines the kind of electricity called static—an improper term, as you will see—is obtained both by mechanical action (the bringing of two bodies in contact and separating them) and by influence.

The contact and subsequent separation of two dissimilar bodies destroy the equilibrium of the ether, and thus electrify the bodies. This is a law which holds good generally, applying to all substances. The latter, however, are divided, according to the way in which they behave when electrified, into *good* and *bad* conductors. The former, which include substances like the metals, communicate their electrification to other bodies that may be in contact with them; the latter, including substances like resin and glass, do not do so. In the former the electricity is diffused over the surface; in the latter it remains where it is at first developed.

It follows from this that, in order to collect frictional electricity, we must insulate good conductors by means of bad ones. The best insulator is glass, covered with shellac, and this is the material that is used in the electrical machines.

The human body itself may be electrified, when it is insulated by being placed upon a stool with glass legs. Mere rubbing of it is enough to produce a charge, especially if the rubbing is done with cat's fur. Certain people, indeed, possess a special predisposition to be electrified in this way, so that sparks can be drawn from them.

When a poor conductor, such as glass or resin, is electrified by rubbing, we notice that it has acquired the property of attracting light bodies. This very old and fundamental experiment proves two things:

1. An electrified body exerts, even at a distance, an influence upon one that is not electrified. 2. Two bodies similarly electrified (*i. e.*, in a similar electrical state) repel each other, while two bodies differently electrified (*i. e.*, in an opposite electrical state) attract each other. It is not worth while to enter into details with regard to these well-known facts.

An electrified body then acts upon neighboring bodies and produces a disturbance in their state of electrical equilibrium. It thus gives rise to new electrical states by producing the phenomenon known under the name of *influence*, or *induction*. This phenomenon of influence is made use of in the best machines employed in medicine.

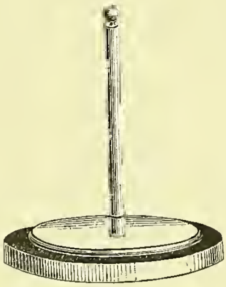
If an insulated cylinder is brought near an electrified body, and, after touching the end of the cylinder, withdrawn again from the body, you can see by the aid of the gold-leaf electroscope that the cylinder which has been subjected to the effect of influence has remained electrified. As the electrified body has not lost any of its charge, we may conclude that with a given electrical mass we can obtain a great quantity of electricity.

Faraday has taught us that the quantity of electricity produced by influence is equal to the quantity of electricity that causes the latter; but, as, in order for this law to hold good, we must take into consideration all the neighboring influences, the charge of the body electrified by influence is always less than that of the electrifying body.

The electrophorus, the most ancient of the induction machines, is based upon this principle of influence. It is illustrated in Fig. 22. You should certainly know the way in which it is used and the theory of its action. By beating the cake of sealing-wax with a cat's skin, we can charge the former with negative electricity. This flat wooden cover, lined with tin, to which is fitted an insulating handle,

rests by one face upon the cake of sealing-wax; its electrical equilibrium is disturbed, and the positive electrical fluid is drawn to the under side of the cover, while the negative is repelled to the top. If we touch the surface of the cover to draw off into the ground the negative electrification, we can then lift the cover by means of the insulating handle. It remains positively electrified. This cover represents the collector of a static machine, from which we can produce a discharge. We can repeat this manœuvre several times and obtain a series of discharges as long as the sealing-wax remains electrified.

FIG. 22.



In addition to presenting these very simple principles, attention must be called to the facts regarding the distribution of electricity upon the collectors. The charge remains upon the surface of the latter and spreads over it, its method of distribution being regulated by the shape of the collector. The latter is almost always cylindrical, and, in this case, the electricity accumulates at its ends. If the collector has a projecting point, the electrical density (the quantity of electrification per unit area) becomes indefinitely great at this spot and the charge then escapes into the air. The layer of electricity, in fact, is kept upon a conductor only by the fact that the surrounding air acts as a bad conductor. It is just as if this layer sought to escape on account of its self-repulsion, and was exerting a constant pressure upon the air about it. This is what we call electrostatic pressure. Experimental facts have shown that at any point of the collector this pressure is proportional to the square of the electrical density. When the air is dry it is a bad conductor, and consequently it allows the charge to stay where it is, except at spots where there are projecting points. But when the air is moist, it becomes a good conductor. This is the reason why static or induction machines can do their work well only under certain atmospheric conditions;

that is to say, when the air is sufficiently dry, and when the machine has a certain temperature. When the air is damp, and when the conductors are cold, aqueous vapor condenses upon the latter, and the charges escape.

Static Machines. Frictional static machines show, then, an irregularity of working; they are, so to speak, subject to caprices, and, for this reason, we have been led to employ the principle of influence in constructing machines.

Medical electric machines are, therefore, of two kinds: frictional machines and influence-machines.

It is needless to say that all of these machines require mechanical work to be expended upon them; *i. e.*, the intervention of an assistant or of some machine to work them (gas or water-power, electric motor), which costs something, and is more or less in the way.

Machines which work by friction alone, and are constructed upon the type of the Ramsden machine, are rarely used. They are of great height, and consequently require a good deal of space; they often get out of order and lose their charge readily. Nevertheless, Arthuis prefers a machine of this class, the construction of which he has perfected, because from it we can get a high tension while using only a weak charge.

Most practitioners resort to the dielectric machines; that is, those working by double influence, the two principal types of which are represented by the Holtz machine and the Carré machine. The former has been practically employed only in establishments devoted particularly to electro-therapeutics. The tendency nowadays is to replace it by machines of the Wimshurst type.

We will, therefore give a description of the Carré and Wimshurst machines.

The former is numbered 0, 1, 2, and 3, according to its size. The No. 2 model is most generally used; it is efficacious, while of comparatively moderate size. This machine is seen in Fig. 23. A succinct description of it will suffice. As to the theory of its action, this is complicated, and need not be mentioned here.

The body of the machine is composed of a wooden frame, two uprights, two plates, one of glass (A), the other of ebonite (B), and a large metal cylinder (C). Between the uprights are placed two steel axles, the lower for the glass plate, which is the smaller of the two, the upper for the ebonite plate.

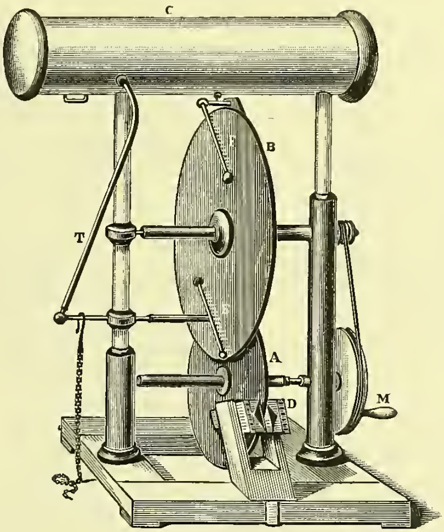
Upon these axles are pillows. One of these (M), which is pro-

vided with a winch and which turns the glass plate, is so arranged that the ebonite plate makes six revolutions while the lower plate is making one.

The glass plate passes between two friction cushions, which are attached to the wooden frame.

Between the two axles, and on the opposite side of the ebonite plate, is attached a copper comb (E), which is connected with a small jointed conductor.

FIG. 23.



Carré's Machine.

A second copper comb (F) placed higher up on the same side is connected with the cylinder of the large conductor by a bearing to which is joined a supplementary inductor of ebonite, placed upon the other side of the caoutchouc plate.

The machine being thus arranged, it is easy to understand how it works.

The glass plate, being partially electrified, produces induction in the first comb, E, through the ebonite plate. The negative fluid flows off by the points of the comb over upon the ebonite, while the comb remains positively electrified.

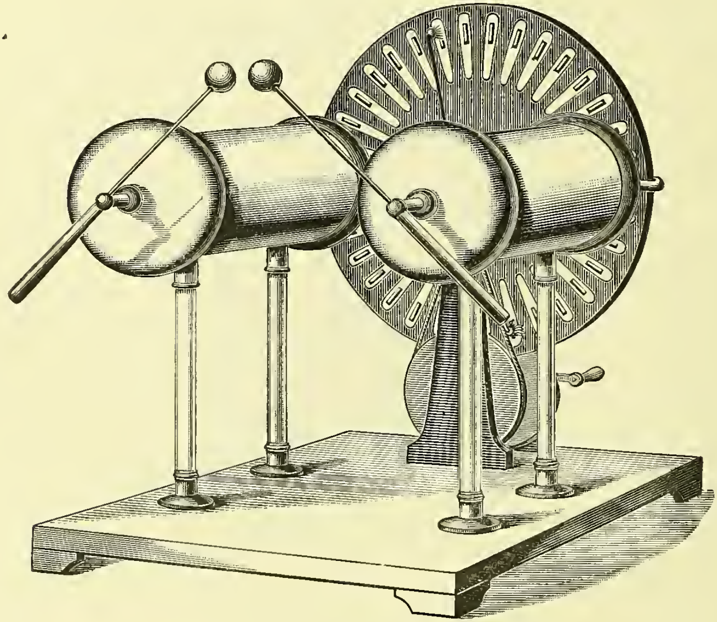
The ebonite plate, being now negatively electrified, exerts an inductive action upon the second comb, F, and its reinforcing plate. The positive fluid which escapes from the points of the second comb

neutralizes the negative fluid of the plate, and finally the large conductor, C, remains negatively electrified.

If now the small conductor, T, is connected with the ground, and the large conductor is connected with the patient, the latter will be subjected to the action of negative static electricity. The reverse arrangement may also be adopted.

The Wimshurst machine, modified by Gaiffé, is gaining in favor. It is arranged as follows (Fig. 24):

FIG. 24.



Wimshurst Machine.

Two vertical ebonite disks, placed parallel to each other and a short distance apart, turn quite rapidly and in opposite directions. Each disk bears metallic sectors, with a metal tongue in the centre of each.

Two conductors run diametrically across the disks perpendicular to each other and inclined 45° to the horizon, and in each a brush is so arranged as to rub against the metal tongues of the disks. These conductors are connected with the ground.

The collectors are represented by metal combs which closely embrace the disks at either end of the horizontal diameter of the latter;

they are attached to cylinders of large surface, mounted upon glass legs.

The machine is self-charging, it works at all times, and does not require any repairs. One of the collectors is charged positively, the other negatively.

Let us now return for a brief space to the subject of the properties of the static machines. You are already aware that sources of electricity, like friction and influence, develop great electromotive force, but little quantity. Static machines, then, are machines of high potential, a property upon which depends the recombining power of the charges which is manifested in the production of sparks.

For the same machine, when revolving with a uniform speed, the length of the sparks varies with the surface of the power conductors. When this is small, the spark is long, slender, sinuous, and frequently repeated; but, when large, the spark is short, broad, straight, and less frequent.

With a machine like that of Arthuis, which is of the Ramsden type, and acts by friction alone, the sparks are long, but are not capable of producing any great mechanical effect. The machines just described furnish a greater quantity of electricity and give rise to larger and more frequently repeated sparks.

The spark, therefore, gives us an empirical idea with regard to the tension and the rate of delivery of a static machine. Its length increases in a simple ratio with the electromotive force, and the frequency with which it is repeated depends upon the rate of delivery of the machine.

This fact is the more important, because it is difficult to measure the charge of a static apparatus. For the latter purpose, in fact, it is necessary to have recourse to electrometers (Thomson's or Mascart's), apparatus which require delicate manipulation, and which can be used only by skilled experimenters.

When we make use in therapeutics of a continuous application of the electric fluid (improperly called the electrostatic bath), we can measure the current employed by means of a very sensitive galvanometer, an instrument which is likewise little adapted to practical use. D'Arsonval, in experimenting with this, found that, with a Holtz machine having four disks, the subject who is placed upon an insulated stool is bathed, so to speak, by a current of electricity which has a negative potential of 3000 volts, but whose intensity reaches a value of only 1:40,000 to 1:25,000 of an ampère.

Thomson, using the Carré machine, has found that the sparks may represent an electromotive force equivalent to that which a battery composed of about 80,000 Daniell elements would give.

In connection with static machines we sometimes use condensers. These are apparatuses constructed upon the principle of the condenser of Aepinus. Two plates separated by an insulating disk (Fig. 25) represent two conductors arranged so that the capacity of one is increased to a considerable amount, which can be readily calculated. This is done without any increase of potential.

FIG. 25.

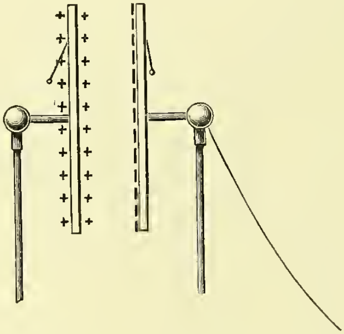
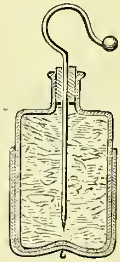


FIG. 26.



The form of condenser which is usually used in static electrization is the small Leyden jar (Fig. 26). The electricity accumulated in this little device penetrates into the interior of the glass, so that we often obtain a succession of discharges rather than a single discharge. In order to prevent the spark from passing between the armature on the inside and the tin coating on the outside, the glass must be carefully varnished. It will also be well to select a jar having a long neck. [The Leyden jar consists of a glass bottle lined within and without to a short distance from the neck with tinfoil. Through a cork in the neck of the jar passes a brass rod, one end of which is in contact with the inner coating of the jar, while the external end is in the form of a knob. Through this knob the interior of the jar receives positive electricity from the prime conductor of an electrical machine; and as the result of induction the surface of the jar is charged with negative electricity. The jar is discharged by connecting the inner and outer parts of the jar by a connecting rod.—ED.]

The electrical machines which we have considered require but little care. They ought to be kept carefully in a dry chamber and

be well dusted. For the cushions of the Carré machine and also for those of machines of the Ramsden type, bisulphide of tin (mosaic gold, bronze powder) is used, thereby increasing the electromotive force and the quantity. Neat's-foot oil is used for lubricating the metallic surfaces which rub upon each other.

In the rooms where the machines are placed it is well, if convenient, to attach the chain that connects the apparatus with the ground to a water-pipe.

The Carré machine needs to be taken to pieces and cleaned from time to time. In doing this, we make use of petroleum for the plates and naphtha oil for the axles.

The stool which serves to insulate the patient should be very carefully attended to. As to the other accessories, their description will come in better in the discussion of electro-therapeutics, when we shall learn how to apply our different kinds of medical apparatus.

Galvanic Electricity. The most important method of generating an electric current is represented by chemical action. It is realized in the galvanic cell, the invention of which, due to Volta, dates from the beginning of the century (1800).

Without giving a demonstration of the theory of the galvanic cell, we should, nevertheless, recall to the mind of the reader in a summary manner the principles upon which the construction of this form of apparatus is based.

When a zinc rod is plunged into a solution of sulphuric acid, hydrogen and electricity are evolved; with the ordinary commercial zinc the action is lively and the bubbles of hydrogen appear upon the zinc, from which they soon rise to the surface of the liquid. If, on the contrary, we use pure zinc, the chemical action is weak, and the bubbles of gas being less numerous remain attached to the surface of the zinc.

If we proceed to immerse a plate of platinum or of copper in the same solution, and in such a way that the second metallic plate touches the zinc, the action becomes energetic, as in the case of impure zinc, but the bubbles of gas are deposited upon the platinum or copper plate.

As soon as the two metal plates are separated this action ceases. From this first experiment we may conclude that the effect produced by the contact of the two metals explains the energy of the reaction in the case of impure zinc. Each molecule of the latter constitutes a little battery by itself.

Let us now arrange the two metal plates in such a way that they

touch each other—not in the solution, but outside of it. We see that the action becomes as energetic as when the contact takes place between two parts that are immersed.

If we place the tongue between two immersed metal plates, the latter gets an impression of a slight sensation accompanied by the development of a peculiar taste.

If we place on the zinc a paper soaked in a solution of potassium iodide, and touch the paper with the second plate, a blue spot is produced due to the liberation of iodine.

The effects thus obtained remain the same when, instead of working with the plates directly, we make the same experiments by interposing even quite long metal wires. And in this case, if we join our two wires and place them near a freely suspended magnetized needle, we obtain at once a deviation of the latter.

We may conclude, from these different experimental facts, that our wires are the seat of a peculiar phenomenon which is the cause of these different actions, including a physiological action upon the tongue, a chemical action upon the potassium iodide, and the physical action upon the magnetic needle. These phenomena are due to the action of the electric current.

When, then, two bodies capable of acting chemically upon each other are placed in contact an electric current is produced at their surface of contact.

The bodies which are charged with electricity by this means have charges of opposite signs. In the example given the zinc has the positive charge, and the acidulated water the negative charge. The zinc being a good conductor, the electricity produced upon it can be collected directly. To collect the positive electricity we immerse in the liquid a conductor which is not attacked by the acidulated water; for example, a plate of platinum, silver, or carbon.

We thus obtain an *electrogenic couple*, to which we give the name of cell. A number of cells in combination is called a *battery*. The two bodies which act upon each other are the *elements;* and sometimes the name element is improperly applied to the couple.

We are in the habit of calling by the name of *electrode* both of the plates which are immersed in the liquid, one being the anode and the other the kathode.

The ends of the electrodes form the polar surface, and the wires which start from them are called the *rheophores* or *conductors*.

Quite often in electro-physiology and electro-therapeutics the name

of electrode is given to the parts of the apparatus in the circuit which are placed in contact with the tissues; in order to avoid all confusion, it is better in the latter case to speak of rheophore-plates or rheophores, and to call the poles of the battery the electrodes.

The sum total of the parts traversed by the current constitutes the battery *circuit.* It comprises the internal circuit and external circuit. In the course of the latter any apparatus upon which the current is to act—the tongue, iodized paper, etc.—is interposed.

When the continuity of the conductor is interrupted or broken the circuit is said to be *open;* when the conductor is continuous the circuit is said to be *closed* or at work. Finally, the circuit is said to be *short* when the conductor has little resistance, or one that may be neglected.

Theory shows that the current in the exterior circuit passes from the positive pole—*i. e.*, from the collecting plate—to the negative pole —*i. e.*, the zinc or other metal attacked by the liquid. Within the cell, on the contrary, the current passes from the negative to the positive pole—*i. e.*, from the zinc to the collecting plate.

It must be noticed that the plate from which the current flows *within* the cell is called the electro-positive element, while the plate toward which the current flows in the liquid is the electro-negative element. On the other hand, the positive *pole* of the cell is the terminal of the electro-negative plate, while the negative *pole* is the terminal of the electro-positive element. Thus the positive pole of a Zn-C cell is the C terminal, the current running from this point through the external circuit to the Zn terminal, and thence from the Zn plate within the cell to the C plate, the Zn being electro-positive to the C.

When the collecting plate is a sheet of copper we find the conditions that Volta had before him when he made his discoveries; we have a voltaic couple.

The hydro-electric couple, of which we have just given a general idea, is almost the only one used in medicine. We shall confine ourselves here to the task of making ourselves acquainted with the different kinds of cells employed in electrotherapy and with the principal properties of galvanic currents.

In practice we should try to secure for galvanic batteries two chief good qualities, namely, regularity and economy.

So many causes hinder regularity of action in a battery that it seems worth while to point out the most important of them.

In the first place, we find impurity of the zinc. This source of irregularity has been demonstrated by De La Rue's experiment. As already stated, the action of pure zinc differs from that of zinc that is not pure. With the former no local current is produced between points upon its surface, and all the current that is generated passes into the interpolar circuit, the hydrogen being evolved upon the collecting plate. With impure zinc, on the contrary, almost the whole of the hydrogen is evolved upon the zinc, and a large part of the chemical action is wasted. The action of the cell, however, keeps on whether the circuit is open or closed; the zinc is consumed without accomplishing any useful work.

There are very serious reasons, then, in favor of using pure zinc. But pure zinc is very expensive and cannot be employed. Very fortunately, an English physicist, Kemp, has discovered that amalgamated zinc possesses the same properties. [Amalgamation consists in coating the zinc with a film of quicksilver.—Ed.] The use of the latter is of the utmost importance in maintaining a regular and economical working of the battery, and it is now adopted by all manufacturers.

The two other causes of lack of constancy in the action that are serious enough to require a remedy are the progressive diminution in the strength of the acid contained in the liquid, and the deposition upon the copper of a layer of hydrogen, which causes the polarization of the electrode. The result of this phenomenon is, that when the circuit is closed the current at once begins to diminish in intensity, and this occurs the more rapidly in proportion as the resistance of the circuit is less. When at rest the couple regains its original intensity.

If we seek for the cause of this phenomenon, we notice that while the battery is working hydrogen is deposited upon the copper. This, on the one hand, increases the internal resistance in each cell, and, on the other hand, diminishes the electromotive force because electromotive force also develops at the surface and gives rise to a countercurrent (a current having a direction opposite to that of the battery current).

When cells are joined together so as to be arranged either for tension or for quantity—an arrangement which we will describe presently—the progressive weakening of the current due to the polarization of the electrode not attacked is even more noticeable than in the case of separate cells, each cell being then traversed by a stronger current than that which itself produces.

Manufacturers have directed their main efforts at removing this defect, and have effected it either by surrounding the collecting-plate with a special medium having the power of absorbing the hydrogen, or by causing the latter to enter into a fresh chemical combination at the instant it is liberated. The carrying out of this latter method has given rise to cells with two liquids.

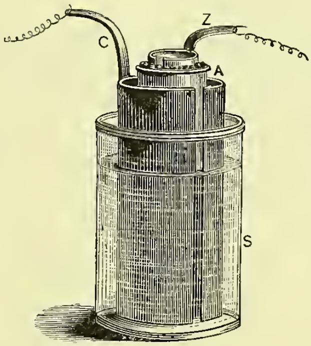
But in spite of all efforts the problem has been solved only in an imperfect fashion; there is as yet no cell that is altogether above reproach.

We should select for medical batteries cells which work only when the circuit is closed and in which the polarization is reduced to a minimum. But besides these, we shall describe some others which are set apart for certain uses.

The best types of cells for medical batteries are those of Daniell and Leclanché, more or less modified.

The Daniell cell (Fig. 27) is a two-fluid cell, the arrangement of which has been varied in several ways. Generally there are placed

Fig. 27.



Daniell Cell.

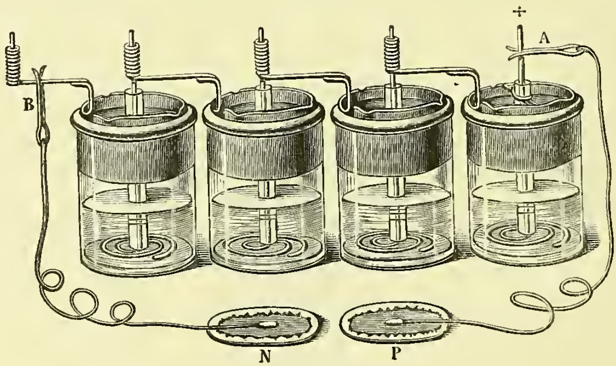
in the jar amalgamated zinc and a solution of sulphuric acid. In the centre of this is set a porous jar filled with a concentrated solution of copper sulphate in which is immersed a copper plate surrounded by a casing filled with crystals of copper sulphate. In practice pure water is simply pumped into the outer jar. The chemical action consists in the oxidation of the zinc, the hydrogen thereby set free passing through the porous jar and displacing the copper from the solution, this latter being deposited upon the copper plate without altering the nature of the collecting-plate.

In this cell no polarization is possible. This combination, theu, is a very good one, and, as a matter of fact, the Daniell cell is very constant. As its electromotive force is approximated equal to unity, it often serves as a unit for the comparison of other cells.

Together with these advantages it has its disadvantages. The solutions placed in the porous jar aud iu the outer jar begin at once to mix, so that a deposit of copper is formed upon the zinc, and as soon as this happens the cell begins to work even when the circuit is opened. Again, after a certain time, the state in which the solutions are saturated is replaced by that in which eucrustiug salts are formed, which cannot be prevented even when the edges of the jars are coated with paraffin.

The modified Daniell cell, nevertheless, may be employed by electriciaus, and we can cite the combinations devised by Trouvé as capable of doing good service.

Fig. 28.



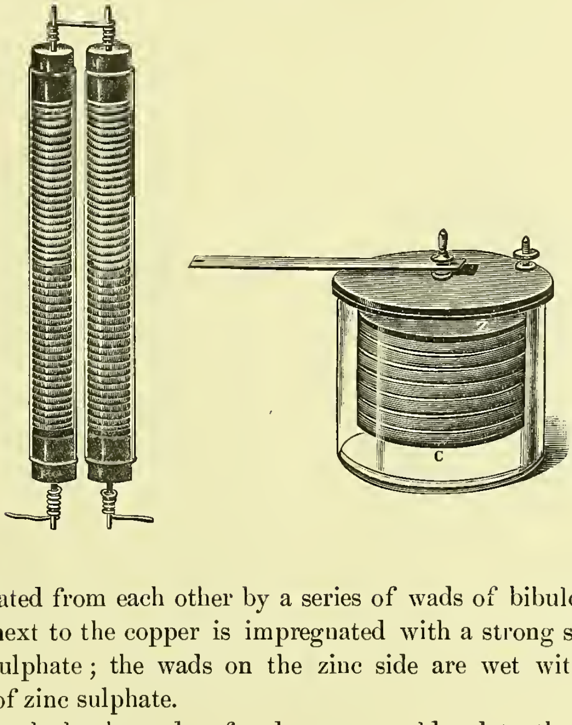
Trouvé has modified this cell by omitting the porous jar invented by Callaud, and has obtained a cell remarkable for its simplicity and its cheapness. (Fig. 28.)

In the centre of a glass jar (a sort of crystallizing jar) is set a copper wire, one end of which, rolled iuto a spiral, rests flatwise upon the bottom of the jar, and the other end forming an upright projecting tip, which is insulated by being surrounded with a tubular glass protector. The zinc is set in the edge of the jar in the form of a large ring. Crystals of copper sulphate are then put in and the jar is filled with water. At the end of a certain time the lower part of the solution is saturated with copper sulphate and the upper part

with zinc sulphate, which is lighter. Nevertheless, in spite of the difference in density of the two solutions, a partial mixture takes place by diffusion, so that some copper is deposited upon the zinc, and the cell works all the time, whether the circuit is open or shut. In spite of this disadvantage, the cell does good service when it is intended to be worked continuously or nearly so.

The second kind of Trouvé cell that is derived from the Daniell cell is the moist battery (Fig. 29). The electrodes, zinc and copper,

FIG. 29.



are separated from each other by a series of wads of bibulous paper. The set next to the copper is impregnated with a strong solution of copper sulphate; the wads on the zinc side are wet with a weak solution of zinc sulphate.

A central shank made of red copper, soldered to the lower or copper electrode, passes through the wads, from which it is insulated by a covering of caoutchouc, and is suspended from a cover of slate or ebonite, or simply from a cork stopper. A lateral rod communicates with the zinc.

When the cell is dry it is quiescent. To set it in action we dip the whole collection of electrodes and wads in water, then let the latter drain off, and close the jar. The cell thus keeps damp for quite a while. It shows great constancy and lasts for a long time.

But it has greater resistance than cells with a free liquid, a resistance which, however, we can vary at will by increasing or diminishing the distance which separates the electrodes.

In Germany the Daniell cell, as modified by Siemens and Halske, is quite often used. This combination has the disadvantage of presenting a very great resistance.

The Leclanché type of cell is one with a single fluid; it is very extensively used and is very well known (Fig. 30). The main jar contains a concentrated solution of ammonium chloride (sal ammoniac of commerce) and a rod of amalgamated zinc. In this jar is introduced

Fig. 30.

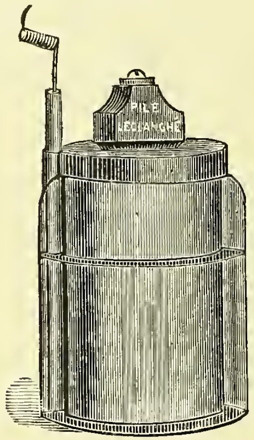
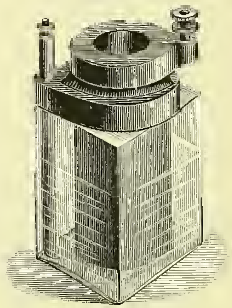


Fig. 31.



a porous jar containing a piece of gas-carbon, surrounded by granulated binoxide of manganese well heaped up. Quite often the porous jar is replaced by plates of binoxide of manganese called agglomerates, by which the carbon is surrounded.

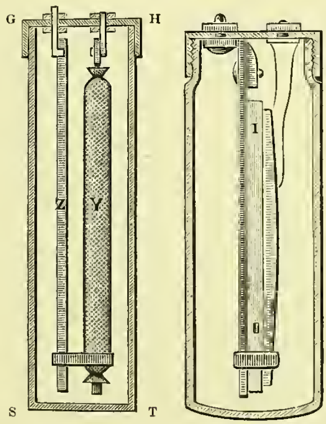
This cell presents the disadvantage of producing incrusting salts, which only partially disappear when the edge of the jar is coated with paraffin. But it works only when the circuit is closed, and so is quite economical. Theoretically, there is a formation of zinc chloride, ammonia, and hydrogen; but, as a matter of fact, the chemical action is more complex. The evolution of ammonia is a disadvantage.

The Leclanché cell has been modified advantageously by Clamond and Gaiffé. In the Gaiffé model (Fig. 31) the zinc rod is immersed in a 10 per cent. solution of neutral zinc chloride free from lead. The agglomerate porous jar of the ordinary battery is replaced by a

hollow carbon cylinder, which serves at once as a porous jar and a collecting-plate, and which contains superimposed layers of binoxide of manganese and powdered carbon. The annular space included between the glass jar and the porous cylinder is closed by mastic, except at the point where the zinc penetrates. The carbon jar, being open, can be emptied and recharged whenever the binoxide of manganese is exhausted. A simple washing out with hydrochloric acid restores its porosity by freeing it from the oxide of zinc which has been deposited upon it.

The chloride of zinc is very soluble and deliquescent; there is no formation of incrusting salts. Moreover, this deliquescence, combined with the fact that the glass jar is stoppered, prevents almost altogether the evaporation of the liquid, and thus insures a regular working of the cell for quite a long time. Oxide and oxychloride of zinc are formed if the zinc is well amalgamated.

FIG. 32.



The electromotive force of this cell is 1.35 volts; its internal resistance is 6 to 8 ohms, which falls to 2 or 3 in the medium-sized models.

The battery of Warren de la Rue, modified by Gaiffe (Fig. 32), is composed of small cells, constructed as follows: An ebonite jar, S T, is closed by a screw-top, G H, to which are attached the elements of the couple, consisting of amalgamated zinc, Z, and a plate of fused chloride of silver, Y, contained in a cloth bag or a silver basin. A cushion of bibulous paper, soaked in a 5 per cent. solution of zinc

chloride, or ammonium chloride, is placed between the plates, thus serving to keep them the proper distance apart. The moist paper may be replaced by a liquid, which is thrown away after the operation. This latter variety of cell is filled at the time of using with the liquid, which in this case may be brine.

This very portable battery may be used to supply the primary current for an induction apparatus; but the model which has no freely circulating fluid, requires to be used frequently.

Marié-Davy has shown that mercuric sulphate can be used to make cells of great service, but small size. It is on this principle

FIG. 33.

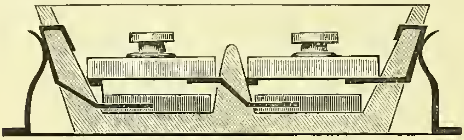
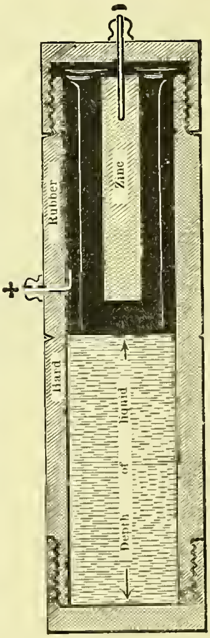


FIG. 34.



that Gaiffe has constructed the little tray-battery which is used to run his small portable induction apparatus. This battery (Fig. 33) is composed of two or three very small cells, made of carbon and zinc, with platinum connections, and mounted in a small hard-rubber tray. A pinch of sulphate of mercury and a little water supply the charge for each cell, a charge which has to be renewed at each application of the battery, but which allows of a period of work lasting for more than half an hour.

Trouvé has likewise utilized the sulphate of mercury in his hermetical or inversion battery (Fig. 34), which is very portable. A hard-rubber cylindrical case is closed by a screw-cap, to which is fitted the zinc. To the wall of the upper part of the case is attached the other element (carbon or platinum). The case is half-filled with a saturated solution of acid sulphate of mercury. When the cell is set right side up it is quiescent, the zinc being outside ot the solution; but when the cell is turned upside down it is ready for action.

Among the bisulphate of mercury cells we shall cite Chardin's apparatus, used by him in the construction of his medical batteries

(Fig. 35). It is so arranged that the zinc and carbon elements are immersed in the liquid only at the moment when use is to be made of them. A rod serves to raise the platform upon which are the jars containing the solution of sulphate of mercury. This prevents the consumption of the latter in the intervals between the applications.

Furthermore, the jars contain a cork cylinder, which, when they are not working, closes their upper orifice and prevents evaporation.

We have yet to describe the bichromate of potassium cells devised by Poggendorf. They are used for various purposes.

The Grenet cell, or bottle-cell (Fig. 36), which is a good deal used for running induction apparatus, is closed by a hard-rubber screw-

FIG. 35.

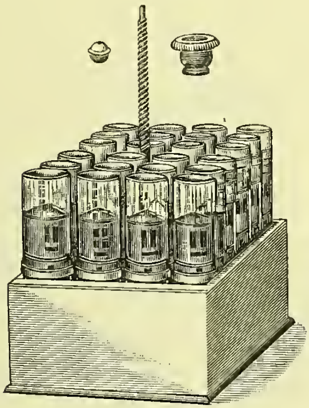
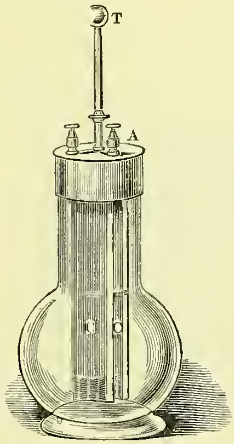


FIG. 36.



cap, A, bearing a pair of carbon-plates, C. Between the two carbons is the zinc, attached to the sliding-shaft, T, which passes through the centre of the cap. The zinc is immersed in the battery fluid at the moment of using, by pressing on the button, T, so as to slide the shaft down into the bottle; the shaft being raised again after each application of the cell. The following solution is used as a battery-fluid:

Water	1000 grammes.
Bichromate of potassium	100 to 105 "
Sulphuric acid	200 to 250 "

A concentrated solution of chromic acid may also be employed, and this enables us to avoid any manifestation of the sulphuric acid.

The Grenet cell is really a two-fluid cell. It has great electromotive force (more than 2 volts), but becomes easily polarized and runs down quickly, so that we use it only when we wish to produce quite a strong effect for a short time.

Chardin has devised a small cell which is convenient for running an induction apparatus. (Fig. 37.) It is divided into three watertight compartments: one, A, is designed for the reception of the zinc when the battery is not working; another, B, contains the carbon, C, and a battery fluid resembling that of the Grenet cell. When it is desired to stop the cell from working the zinc is placed in its special compartment, and a rubber stopper seals hermetically the orifice of the compartment containing the fluid.

Fig. 37.

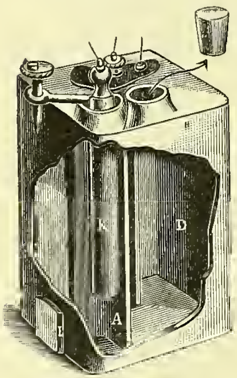
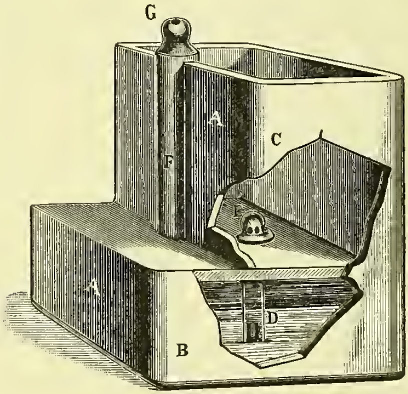


Fig. 38.



Chardin also uses for bichromate cells an arrangement, which he cells a circulation cell. (Fig. 38.) Two jars—one above containing the elements of the cell, and one below containing the battery fluid—are connected by a tube, which starts at the bottom of the upper jar and dips down into the fluid. The lower compartment communicates with the external air by a shaft, to which is fitted a rubber tube, that may or may not be furnished with an inflating bulb and stopcock. Every charge of air driven into G acts upon the fluid in the lower jar and makes it rise into the upper compartment, where it comes into contact with the elements of the cell. This rise of the fluid can be checked at any point whatever.

We will point out later those batteries composed of bichromate cells that are designed to furnish quantity currents.

We have now become acquainted with the principal arrangements for utilizing chemical action directly. Some years ago investigators made an important step in advance by devising an apparatus which admits of utilizing the polarization of the electrodes as a source of electricity.

The name of accumulator is given to the secondary cells in which the current is developed by polarization of the electrodes. These accumulators, the construction of which has recently been much improved, are of service in cases in which we require calorific or luminous effects. The principle upon which they are based is that which we discussed when speaking upon the subject of the polarization of electrodes. [They are often called storage batteries.]

Every time that we produce chemical work in a cell a process of polarization is set up upon the surface of the electrodes. Suppose, for instance, we make a galvanic current act upon a voltameter, and at the end of a certain time connect the electrodes of the voltameter with a galvanometer. We shall then be able to detect the existence of a current the direction of which is opposite to that of the original current. The voltameter, accordingly, has been charged, and its electrodes consequently are capable of developing a current.

In a general way an accumulator is such a voltameter. The elements, which are thus liberated upon the surface of the electrodes, recombine when the latter are put in connection by closing the circuit, and then give up the electric energy which they had absorbed at the moment of their decomposition.

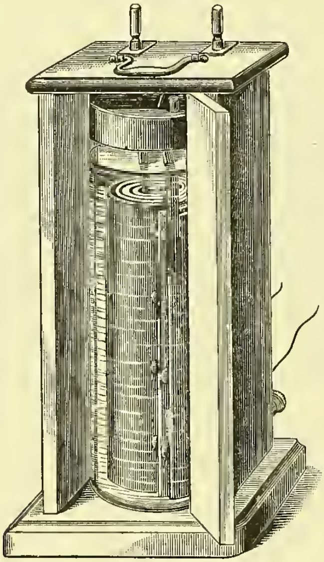
The first accumulators were voltameters with platinum electrodes. In 1859 Planté made a considerable step in advance when he discovered that we get much better results if we use lead plates for electrodes.

The Planté accumulator (Fig. 39), which is still made use of by Trouvé, is composed of two leaden plates rolled spirally and parallel to each other and kept apart by rubber-bands, which are rolled in with them. The plates dip in a bath made of a 10 per cent. solution of sulphuric acid. In the lid is a hole which serves to renew the liquid and to allow the escape of gas which may be evolved during the passage of the charging current. The charge is obtained by a current from any source not too strong and having an electromotive force of more than 2 volts. The current, by decomposing the solution, causes a deposition of oxygen upon the positive plate and of hydrogen upon the negative plate. In the former case peroxide of lead

(PbO_2) is formed; in the latter case, on the other hand, any oxide which may be present upon the surface undergoes reduction. We prepare the cell—*i. e.*, impart activity to it—by passing through it successive charges in opposite directions, ending by sending a current through it which has the same direction all the time. Such a cell keeps charged for several days.

The accumulators at present employed are in general made with lead electrodes, which, by being melted and run into moulds, are given the shape of an open-work grating. In each of the compartments of the negative plate is placed some minium (red lead), while those of the positive plate are filled with litharge. The plates are

FIG. 39.



set vertically in jars composed of some insulating material (glass or hard rubber), and are separated from each other by sticks of cane or by rubber rings. The jars are filled with a 10 per cent. solution of sulphuric acid. While the apparatus is being charged the hydrogen produced goes to the positive plate and reduces the litharge, with the formation of metallic lead. The oxygen coming into contact with the red lead upon the negative plate, converts it into lead dioxide. The accumulator is fully charged when free gas is evolved, instead of being taken up by the electrodes.

It takes less time to prepare and charge these accumulators than it does for the previous variety of Planté.

Choice of a Medical Battery. These being the various elements which may be employed in the construction of batteries designed for different medical purposes, it now remains to select from them such as are suitable for each of these purposes, and to arrange them into different forms of apparatus whose properties and value we shall be able to ascertain.

In practice electricity is used either for making applications to the human body, the resistance of which it has to overcome; or for the production of calorific or luminous effects. These two distinct objects are attained by means of distinct forms of apparatus. Let us consider first the question of the medical battery, properly so-called.

In order to select our elements properly and to arrange them in such a way as to secure the effects we desire we must acquaint ourselves somewhat more thoroughly with the properties of the electric current.

Let us take the case of a cell. When the circuit is open the poles of the cells have a certain potential difference which depends upon the electromotive force, E, and which we can determine by means of the electrometer. If we close the circuit by interposing a tin-foil condenser—an apparatus which we shall describe later—a rupture of equilibrium is produced until the difference in potential of the two armatures of the condenser is equal to the electromotive force of the cell.

A rupture of the state of electrical equilibrium can also be obtained by connecting the poles by means of a conductor. But in this case the equilibrium is not re-established, the conductor tends to effect a disappearance of the difference of potential, while the electromotive force tends to maintain this force.

The conducting wire, hence, acquires new properties; it becomes the seat of a current, the direction and intensity, I, of which can be defined.

Furthermore, the current meets in its passage a certain resistance, R, depending on the length, size, and material of its conductor, so that there is a gradual fall of potential from one pole to the other when the circuit is closed.

Designating this resistance by R, Ohm's law, the intensity equals electromotor force, E, divided by the resistance, expressed by the formula

$$I = \frac{E}{R}$$

or

$$E = IR.$$

This is the most important formula of electrical science. Using the practical units previously defined, we may express this formula in the following terms: the intensity of a current expressed in ampères is equal to the quotient of the electromotive force expressed in volts, by the resistance of the circuit expressed in ohms.

Suppose that the resistance is invariable and the current constant. Then in each unit of time the electromotive force will, so to speak, raise a quantity of electricity to the height, E, and will perform an amount of work equal to EI. This work done per second represents a power, P. That is, P, expressed in watts $=$ EI, or, substituting the value of $E = IR$, $P = I^2R$. As has been already pointed out, this is determined, as in the case of the power developed by a fall of water, by two factors, the volume of discharge (I) and the height of fall (E).

The quantity, Q, being the amount of electricity delivered in a second of time, T; $Q = IT$, or the quantity in coulombs, is calculated by multiplying the current strength, expressed in ampères, by the time, in seconds.

When the cell is connected simply with itself—*i. e.*, has a short circuit, the resistance of the conductor is practically zero; then the resistance, R, is represented by the internal resistance of the cell.

But when things are so arranged that a certain amount of external work is done, the current encounters in the external circuit a more or less notable resistance.

The factor, R, combines, then, two terms, which are usually denoted by r, or the internal resistance of the cell, and R for the external resistance of the circuit.

If we take these two fractional parts of the total resistance into account, Ohm's formula becomes

$$I = \frac{E}{r + R}.$$

The introduction of resistance results, therefore, in a diminution of the intensity, and this resistance may become great enough to reduce the intensity practically to zero, *i. e.*, to make it insufficient for the performance of any work.

We can make this fact obvious by connecting a cell alternately with a galvanometer and a voltameter.

Suppose we put a Daniell cell in connection with a galvanometer. We get a deviation of the needle indicating an intensity of 125 M. A. (milliampères). Now let us pass the current through both a galvanometer and a voltameter. The galvanometer needle is then

deviated scarcely at all, and there is no electrolysis produced in the voltameter.

As a matter of fact, this is what happens. The internal resistance of the cell being 8 ohms, and that of the voltameter 1000 ohms, we have from the preceding formula (the electromotive force of the Daniell cell being 1):

$$I = \frac{1}{8 + 1000} = 0.000992 \text{ ampère},$$

or less than 1 milliampère.

The resistance offered by the human body being greater than that of the voltameter, it is necessary to have forms of apparatus capable, when there is a certain resistance to be overcome, of furnishing the proper electromotive force for the purpose.

This is the object that is effected by the various arrangements of cells. The formula shows that this coupling, when employed for medical purposes, ought to be so done as to produce relative increase in the electromotive force as compared with the resistance. The desired effect is obtained by means of the arrangement in series, *i. e.*, that in which the positive pole of one cell is joined with the negative pole of the next.

If we connect in this way two cells which, taken singly, are without action upon the voltameter, we may now get an energetic chemical action. What have we succeeded in securing by means of this arrangement?

By coupling the cells in series we multiply the electromotive force by the number of cells; a force, E, for one cell becomes n E for n cells. So, too, we multiply the internal resistance by the number of cells; r becomes nr. But R remains the same. Hence we have

$$I = \frac{n\,E}{nr + R}$$

or

$$I = \frac{E}{r + \frac{R}{n}}.$$

The denominator having become smaller, there is produced a notable increase in the value of I.

In the example that we selected, we have

$$I = \frac{2}{2 \times 8 + 1000} = 0.0019 \text{ ampère};$$

i. e., nearly 2 milliampères, instead of less than 1.

A second method of coupling is represented by the *arrangement for quantity.* This is produced when we join like electrodes, *i. e.*, zinc with zinc, and copper with copper. This is called arranging in *multiple arc.*

The same formula shows us that this kind of coupling gives a different result from the former. Here the electromotive force remains the same, but the internal resistance is divided by the number of cells. The coupling for quantity is equivalent to the employment of a single cell of the same electromotive force, but of larger surface. In this case

$$I = \frac{E}{\frac{r}{n} + R}.$$

If in this case the external resistance be great, we shall get, using the example that we had before (of a Daniell cell):

$$I = \frac{1}{8/2 + 1000} = 0.000995 \text{ ampère } (= 0.995 \text{ M. A.}).$$

With a single cell we had 0.992 M. A. Hence the increase of intensity in this case is insignificant. It is no longer so when the external resistance is slight. For simplicity let us neglect this resistance, R. Then in the coupling for tension we get

$$I = \frac{n\,E}{n\,R}$$

or the intensity remains the same; in the coupling for quantity we get

$$I = \frac{E}{\frac{r}{n}}.$$

The intensity is here considerably increased; it is doubled when we use two cells instead of one; from $\frac{1}{8}$ of an ampère it becomes $\frac{1}{4}$ —*i. e.*, from 125 M.A. it rises to 250 M.A.

We may conclude from this that when we have to use our battery for overcoming a large external resistance we should arrange the cells in series, and that, on the other hand, the arrangement for quantity must be chosen when the battery will have to overcome only a weak resistance. In certain cases we might need a *mixed* method of coupling, which consists in arranging groups of cells in series, the cells of the separate groups being arranged for quantity.

By the aid of these data it is possible to show what properties a medical battery ought to possess when it is designed to accomplish a certain known result and at the same time overcome quite a great external resistance.

Let us consider once more the formula

$$I = \frac{n\,E}{nr + R}.$$

This shows, in the first place, that the cells of a medical battery should have a certain electromotive force, in order that the number of these cells shall not become too great and the battery itself consequently too cumbrous.

In the second place, it renders apparent the necessity of choosing cells which do not have too great a resistance, since in this case, too, the number of cells would have to be large. There are, in fact, cells of less resistance which, for the same number of them, afford the greatest current strength.

The resistance of the human body being great, the battery, in order to obtain a current whose intensity can be varied at will from 1 to about 35 milliampères, must contain quite a large number of elements. Writing our formula in the second way, we have

$$I = \frac{E}{r + \frac{R}{n}}.$$

It can be seen at a glance that if the external resistance be large compared with the internal, the intensity will increase nearly with the number of cells, since the denominator becomes smaller in proportion as n becomes greater.

The number of cells necessary will be smaller in proportion as the internal resistance of each cell is weaker. And, indeed, the smaller r is the greater will be the intensity of the current for the same number of cells.

We may therefore enunciate the following conclusions:

To make up an ordinary medical battery we should select cells having quite a considerable electromotive force (from 1 to 2 volts) and a weak internal resistance, and should arrange these cells in series or multiple arc in sufficient numbers to obtain a current of the desired intensity.

Theoretically it would seem advantageous for the cells selected to have a great electromotive force. But in practice it is necessary for us to be able to vary the intensity of the current progressively while the resistance remains the same. The reader will understand that ordinarily we vary the intensity by bringing into use a constantly increasing number of cells, and that often the switches take on these additional cells in pairs (*i. e.*, 2 by 2).

If the electromotive force of each cell were too great, it would be impossible to increase the intensity of the current gently and without shocks.

It still remains to say a word about what are called "tension batteries," the use of which has been recommended by some specialists. The latter at one time thought that in order to obtain the maximum useful effect from a galvanic current they had to select cells of weak electromotive force and great internal resistance. What should we think of this sort of arrangement? This question has been already decided. Our preceding formula shows that elements of weak electromotive force and great internal resistance, when arranged in series, give a current of weak intensity. Such cells, when the circuit is closed and offers more or less resistance, can furnish a current of appreciable intensity only when grouped in considerable numbers. But the properties of an arrangement of this kind are somewhat peculiar, and this fact should be known.

When the battery is composed of a great number of cells of weak electromotive force and of great resistance it presents the peculiarity of having in open circuit a high potential-difference between its poles and of producing at the moment of closing the circuit a very great fall of potential. Hence at each closure of the circuit there are produced discharging effects which are more marked than in the case of cells having the opposite properties. It is perhaps for this reason that certain practitioners have ascribed to this kind of battery a very marked physiological activity.

The formulæ with which we have become acquainted will show this fact clearly.

If we denote by e the difference of potential between the terminals of a battery of n cells in series, this value is equal to n E; or, according to Ohm's formula,

$$I = \frac{n\,E}{nr + R}$$

or $e = n\,E = I\,n\,r + IR$.

This means that the total electromotive force may be considered as partly employed in driving the current through the external resistance R, and partly in driving it through the internal resistance r. This latter part is called by Thompson the *lost volts;* the remainder being the useful volts, which would be measured by a voltameter set between the terminals. If we call the available volts e', we may write $e' = IR$; whence $e - e' = Inr$, or the dif-

ference between e and e′ will increase in proportion as n and r become greater.

If we wish to obtain discharging effects, secured in this case by the fall of potential occurring when the circuit is closed, it would be better, as will be seen, to make use of condensers or some forms of induction apparatus. The medical battery adapted for producing the effects that we wish to get in a closed circuit should be composed of cells having the properties previously enumerated.

The best cells from this point of view that are in use in France are Gaiffe's (of medium size), Chardin's bisulphate cells (of medium size), and Callaud-Trouvé's.

The ordinary zinc-carbon cell in which an acid solution of bichromate of potassium is used has an electromotive force of about 1.7 volts, and will be found efficient. Care must be taken to keep the zinc out of the solution except when the battery is in action.

[As an American cell the "Axo" is acknowledged to fulfil the requirements for medical use best. It is an improved modification

Fig. 40.

"Axo" cell complete.

Fig. 41.

"Axo" porous cup.

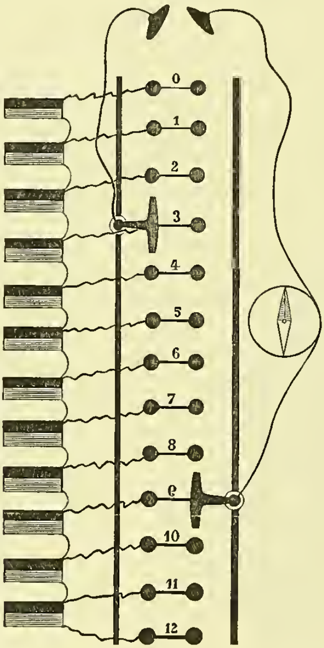
of the Leclanché cell, furnishes an electromotive force of 1.6 volts with constant and low internal resistance, and is closed to prevent evaporation; its power diminishes very slowly and recuperates rapidly when at rest. A battery composed of 50 or 60 of these cells may be used constantly for office-work for at least one year without requiring any attention, if care is taken to prevent short circuiting by having the switches always turned off and the conducting-cords removed when not in use.—Ed.]

A medical battery is frequeutly composed of 20 to 40 cells. It is indispensable that these should be connected with an apparatus enabling us to make use of a variable number of these cells.

In most cases we can, without inconvenience, pass from a current intensity furnished by n cells to that which $n + 1$, or even $n + 2$, cells afford, provided that we can do this without interrupting the current.

With this object in view we make use of an accessory apparatus known by the name of a collector. The collector may be either single

FIG. 42.



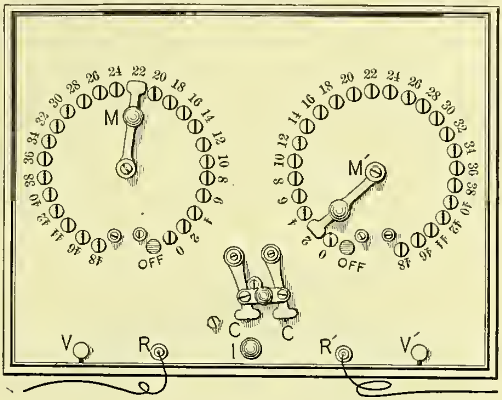
or double. The latter, or double switch, is usually so arranged as to admit of a progressive reversal of the direction of the current without any shocks being produced.

The simple or rectilinear switch is composed of a frame of wood, upon which are placed a set of buttons, marked 0, 1, 2, 3, etc., or 0, 2, 4, etc. A metallic bar is fixed over the buttons and is connected with them by a slide, which can be pushed back and forth with the hand.

By placing one of the conducting-wires at the end marked 0 and

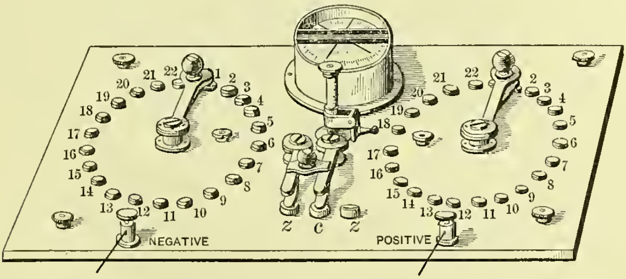
the other wire from the positive pole, at the end of the metal bar, we can, by pushing forward the slide, introduce the cells into the circuit, one by one. The slide is so made as to come in contact with one button before it has quite broken contact with the button before it, an arrangement which insures the continuity of the current. The switch can be so arranged that the cells are introduced, two by two.

FIG. 43.



The double switch is a combination of two simple switches, according to the annexed plan (Fig. 42). In most office-batteries the switch has a circular arrangement (Fig. 43).

FIG. 44.



In the switch made by Gaiffe the negative pole always corresponds to the button marked with the lowest number.

The cells can be introduced into the circuit either one by one or two by two, according to the way in which the wires of the battery are attached to the buttons. Usually the second method is the one

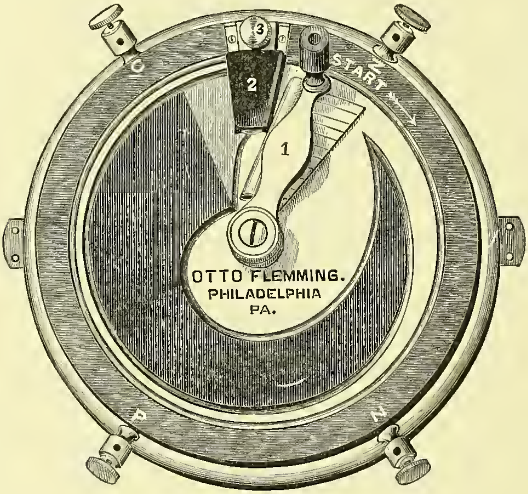
adopted. But the plan of Fig. 42 shows the arrangement which allows of the introduction of the cells one by one.

One of the pointers being upon the button marked 3, and the other upon the button marked 9, we have the current given by 6 cells. In Trouvé's double switch (Fig. 44) two groups of cells can be introduced in succession and one by one into the circuit. The medical batteries of Chardin have an analogous switch.

The double switch has the advantage over the single one of enabling us to bring into the circuit any section whatever of the battery, an arrangement which, when only a limited number of cells is put into action, prevents us from being obliged to use the same cells all the time.

[By far the best current-controller is that known as the Massey-Flemming current-controller (Fig. 45), which, however, cannot be

FIG. 45.



Massey-Flemming Current-controller.

reversed. Its function is to vary the current at will by rapidly increasing or decreasing the resistance of the circuit, from a fraction of a milliampère to the full strength of the battery without shock. It consists of a porcelain plate, provided with a sickle-shaped conducting area of graphite (soft pencil), broadening and thickening up to the terminal, where the graphite unites with a metallic surface, which is in direct contact with the battery without any material resistance. When the crank (1) (Fig. 45) is placed to the right of

the hard-rubber bridge (2), the contact comb of the crank rests entirely on the porcelain and the current is broken; moving it slightly forward it soon touches the sickle-point, and the graphite mark permits the least amount of current to pass through, since the current must pass over the whole area of graphite. By turning the crank slowly and steadily onward there is a gradual increase of current without shock until, finally, the metallic surface is reached, when the whole power of the battery is turned on. A reversed action turns the current off. If the motion is made slowly, the increase and decrease are exceedingly gradual and the meter-needle points constantly to the exact current strength of the moment without oscillation. By its use a more economical wear of the cells results, as all cells are worked alike. It may be used with a small or large number of voltaic cells or in connection with an incandescent light circuit for medical galvanic work, but cannot be used for actual cautery.

Special attention should be paid to the following points in using this instrument:

1. Always place the turning-crank on the bare porcelain, as shown in the engraving, before applying the electrodes to the patient, so as to be sure that the full resistance is interposed; otherwise an unpleasant or even dangerous shock to the patient might result.

2. After the electrodes are in place turn the crank down and toward the broader end of the graphite slowly until the meter shows the desired strength of the current.

3. If using an incandescent current, never bring the metallic parts of the conducting-cords or electrodes together unless the crank is on the thinnest part of the graphite.

4. Keep the apparatus free from dust.

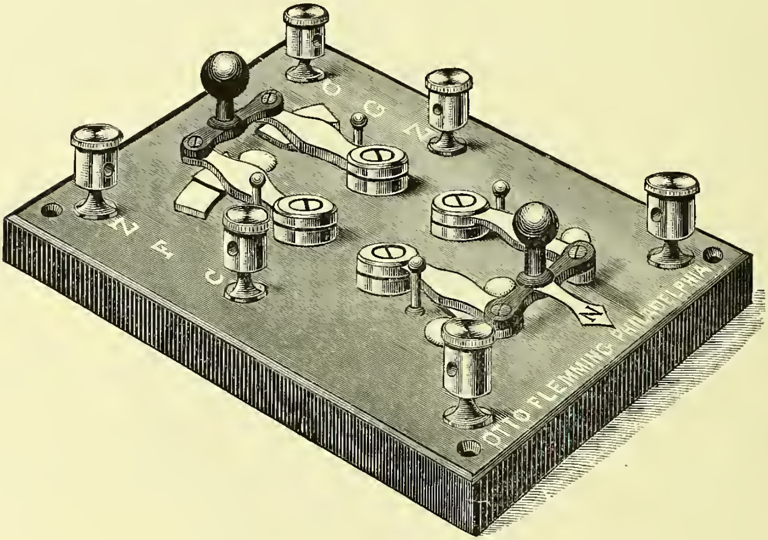
5. Renew the graphite covering on the porcelain plate as often as marks of wear are visible by rubbing graphite over the circumscribed area from a *very soft pencil.* If the current is too strong at the very point of the graphite, rub some off and recoat it more lightly.—Ed.]

With the switch two other acccssories are almost always associated: a commutator, which allows of a sudden reversal of the direction of the current, and an interrupting-button (Fig. 44).

One of the commutators most used for medical batteries is that of Ampère. [A very useful commutator, more largely used in America, is the "De Watteville" Current Combiner and Commutator (Fig. 46). It is a convenient arrangement of switches for the simultaneous ad-

ministration of galvanic and faradic currents, whenever both of these currents are useful. They may be elicited simultaneously by placing the double switch in a parallel position so as to rest its right portion of the one switch-spring on the flat plate marked with letter G (galvanic) and the left portion of the other switch-spring on flat plate marked F (faradic). The faradic apparatus is started, and all switches pertaining to the galvanic as well as to the faradic apparatus must be set for actual work. The two currents are then to be regulated each by its own controller until the desired degree of strength of each current is reached; the galvanic by the graphite controller and the faradic by the controlling-screw which moves the outer helix of the

FIG. 46.



Du Bois-Reymond coil (see Fig. 69), and by placing the double switch on the button P or S (prim. or second), respectively. For using the simple galvanic current move the double switch to the extreme right, so as to rest one part of the double switch on flat plate G, and the other on the button in the middle. For faradic currents move the double switch to the extreme left so as to rest on the flat plate F, with the button in the middle.

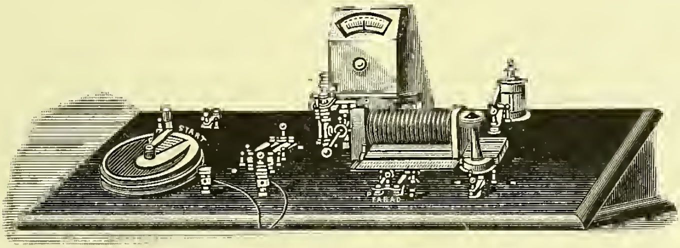
The second double switch is the commutator or pole-changer with index N always pointing to the negative pole, whether it be turned to the left or right terminal post (conducting-cord) or whether used in simple or combined currents.—ED.]

We rarely, however, have to produce an abrupt reversal of the current; on the contrary, it frequently occurs that we have to avoid it. The double switch and current-controller (Figs. 44 and 45) allows of the current being reversed in a progressive manner. The pointer directed upon the button marked with the highest figure is left in place and the other is turned around the dial; the instant that the latter pointer reaches the button marked with the same number as that occupied by the other the current is reduced to zero; when the pointer is carried still further the current becomes appreciable once more, but has the opposite direction.

We may also carry the former pointer backward to the point where the current becomes zero, and then turn the outer pointer forward.

Complete medical batteries provided with galvanic and faradic apparatus, current-controllers, commutators, milliampèremeters, etc., may be set in cupboards or in special cases, it makes little difference

FIG. 47.



Electro-therapeutic-gynecological Apparatus.

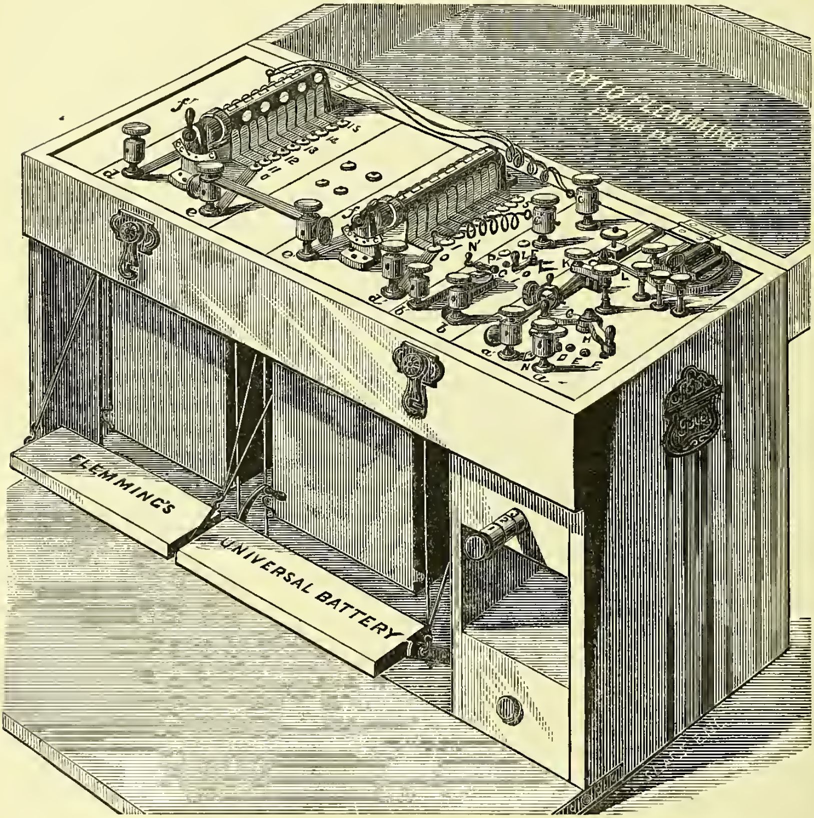
which, provided that they are protected from evaporation and provided with the necessary accessories (Fig. 47). We shall have occasion to return later to some of these.

For other purposes, such as galvano-cautery, the production of luminous effects, or the working of motors, we have recourse to cells of high electromotive force (bichromate or chromic acid cells). [Such a battery as the universal battery, shown in Fig. 48, is capable of performing all this work.

This battery consists of two systems of ten zinc and carbon plates. Each is suspended from two hard-rubber platforms (Fig. 48, *f* and *f'*) placed side by side in the top of the box. A brass spring is connected to each plate by a screw passing through the platform, and presses against a cylindrical commutator, by turning which the plates can be connected for quantity—*i.e.*, all carbons and all zincs con-

nected together, each lead to a binding-post, *d e*, *e′* and *d′* ; the carbons of the first system being connected with the zincs of the second system by the strip of brass connecting the binding-posts *e* and *e′*; or for intensity—*i. e.*, zincs and carbons being connected with each other alternately. Alongside of the platform *f* is another one, upon which are mounted the binding-posts *c* and *c′*, which are connected

Fig. 48.



by flexible cords carrying pins with the plates of the system in such a manner that the cord from the post *c′* leads to the spring marked O, the pin being inserted in a hole drilled into the head of the screw connecting the spring with the plate below the platform. The other post *c* carries a double cord, the pins of which may be inserted into any of the screw-heads of the systems of plates, and thus any number of pairs from one to twenty may be brought into action with-

out interrupting the current. The posts *b* and *b′* serve to connect the cords leading to the electrodes. Upon the same platforms are also mounted a polarity-changer and a two-point switch for interrupting the current if it is desirable; these appliances being used where an intensity of current is made use of. At the end of the box a galvano-faradic apparatus is inserted, which may be removed and used separately, and away from the battery.

In the lower portion of the box are two movable platforms, which may be raised or lowered by a treadle, to which they are connected by cords running over rollers. Upon these platforms are placed two hard-rubber cups, partitioned off into ten compartments each, and in these the exciting liquid, a mixture of bichromate of potash, sulphuric acid, and water, is contained. These cups being immediately beneath the system of plates, suspended from the platforms, when raised by the treadle cause the plates to be immersed in the fluid, and thus a current is established which varies in strength according to the amount of surface of plates exposed to the action of the acid. A ratchet hook at the bottom of the box, by engaging in the bar of the treadle, will keep the cups at any desired height, so that the foot may be taken off; and by disconnecting the cords of either one or the other of the movable platforms, either one or the other of the cups alone may be raised when only a comparatively weak current is desired. Below the faradic apparatus are drawers for containing the instruments, connecting-cords, etc. The size of the box containing the whole apparatus is twenty-eight inches long by twelve inches wide and sixteen inches high, and is, therefore, not too large to be easily moved.

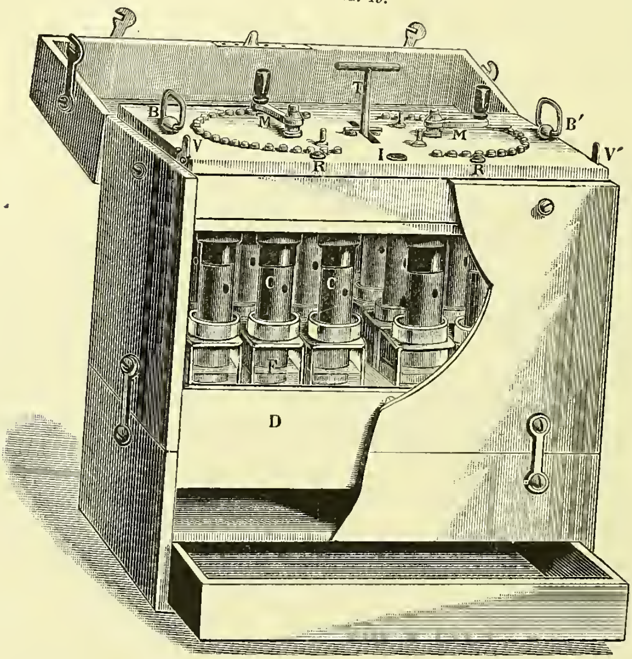
When a more simple apparatus is desired for the purpose of using galvanic currents for medicinal purposes, we may employ an apparatus such as is employed in Figs. 49, 50, 51, and 52.—Ed.]

We may now recall the fact that the practitioner will require one or two cells in order to work his induction apparatus. For this purpose the trouble is in making a choice. The portable forms of apparatus contain the battery for furnishing the current. For the office we make make use of a bottle-cell, of one Grenet cell (medium or large size), or one of the other cells which we have previously described, such as the Gonda Axo cell, Figs. 40 and 41.

[The storage battery has become so generally used, chiefly for illuminating and cautery purposes in medicine, that a description of the principle on which it is constructed is in place, although this has

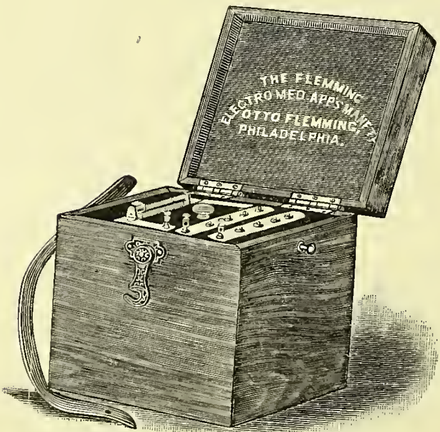
already been mentioned. When water is decomposed by the passage of electricity through platinum plates, which are immersed in it,

Fig. 49.



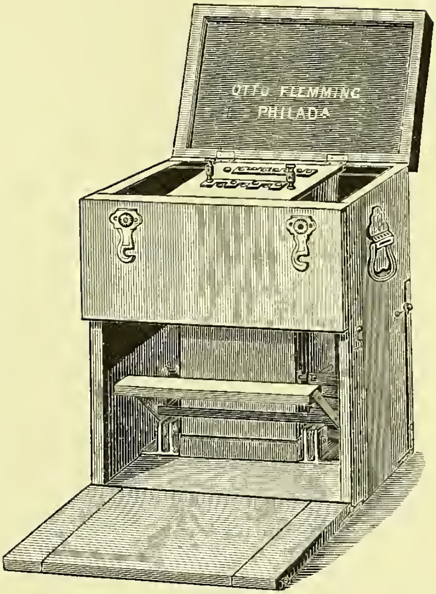
Bisulphate of Mercury Battery.

Fig. 50.



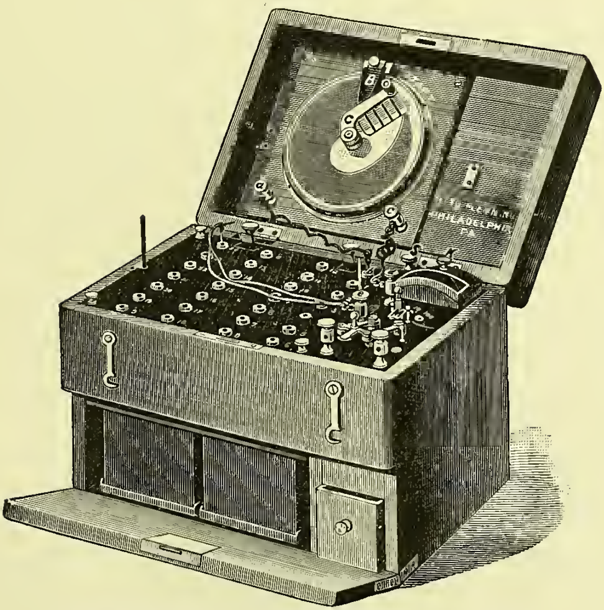
Portable Single Cell Cautery Battery.

Fig. 51.



Non-portable Cautery Battery.

Fig. 52.



Bichromate Battery, with Millampèremeter, and Controller.

oxygen gathers in the positive plate and hydrogen in the negative. When the external cell is completed these gases recombine to form water and generate an electric current, so that the electric energy is set free by chemical recomposition. The Planté storage battery is the one upon which all electrical apparatus of this kind is based. When acidulated water is decomposed by lead electrodes, the oxide of lead coats one and hydrogen the other. If the lead plates be now connected, a recomposition takes place, and a new electric current in an opposite direction is developed. Finally the plates are reduced to plumbic oxide on both sides, and this being acted on by the acid is reduced to plumbic sulphate. When the battery is charged a second time the plumbic sulphate is decomposed and dissolved and the lead plates can now take up the oxygen and hydrogen again. The original Planté storage cell is now obsolete, as it is very slowly charged and otherwise difficult in practical use, and is supplanted in principle by Faure's modification, which consists in covering the sheets of lead with a paste of red lead and sulphuric acid. The paste is held in place by means of parchment and felt, and the paste-covered sheets are then immersed in an acidulated water. Electrolysis with an alternating current is now employed, and in a short time the red lead, Pb_3O_4, or minium, is changed to PbO_2 on one plate, and spongy lead on the other. The connection of the lead sheets causes recomposition with the development of an electric current. There are many modifications of the minor details of storage batteries made by different manufacturers. The storage battery of to-day is imperfect, and all of them get out of order with provoking irregularity. It is said that many hundred patents based on these principles have been issued, none of which have accomplished all that is necessary for their success.—Ed.]

It only remains for us to become acquainted with the tinfoil condenser, an instrument introduced into electro-therapy some years ago. Its object is to enable us to produce with the galvanic current discharging effects approximately equal to those caused by induced currents.

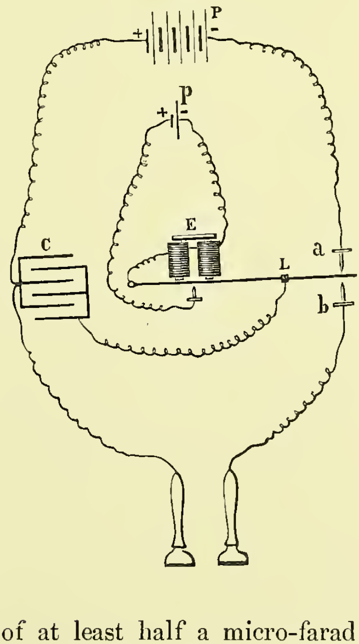
The instrument in question is of very simple construction, but of quite delicate workmanship. Sheets of tinfoil are superimposed upon one another, being kept separate by means of paraffin paper, which plays the part of an insulator. One edge of each sheet projects a little beyond the paraffin paper. The rims thus left free are super-

imposed in sets of two, in such a way that we have a tier of sheets in pairs alternating with a tier of sheets that are not paired (see Fig. 53).

The whole is compressed, immersed in boiling paraffin, and after cooling is inclosed in a box, the lid of which has two terminals connected with the edges of the sheets of foil.

The instrument, while differing altogether from the electrostatic condenser in its comparatively small size, presents a very considerable surface for condensation, and, consequently, has quite a great capacity. For physiological and medical use it is arranged so as

FIG. 53.



to have a capacity of at least half a micro-farad or oftener of one micro-farad, being divided or not into fractions of 0.1 to 0.5 micro-farad.

Guillemin has demonstrated that a tinfoil condenser can be charged almost instantaneously to the point of saturation by means of an ordinary battery, owing to the large quantity of electricity which the latter is able to furnish in an extremely short period of time. This instrument has received various applications. Its use was introduced into medicine some years ago by Boudet, of Paris.

Knowing now the various forms of apparatus designed to furnish

a galvanic current, we have left to us the task of determining the physical conditions under which we are to work them.

Ohm's formula $\left(I = \frac{E}{R} \text{ or } \frac{n\,E}{nr + R}\right)$ enables us to solve various problems; but in practice calculations of this sort are got rid of, thanks to the use of different sorts of measuring-apparatus, which should be considered as indispensable accessories to medical batteries.

The electromotive force of the cells which we employ is important for us to know, and might be deduced from the above formula. But as it varies only slightly, it may be determined once for all, and most books and catalogues give a table of the electromotive forces of the principal cells and sometimes also of their resistances.

Following are some data regarding the cells which we have described:

TABLE OF ELECTROMOTIVE FORCES.

Daniell cell	1.079
Callaud-Trouvé cell	0.98
Gaiffe cell	1.35
Bisulphate of mercury cell	1.526
Bichromate of potassium cell	1 9 to 2.026

The most important measurement, that of the intensity of the current, is furnished by the galvanometer, an indispensable instrument, which ought to be annexed to every medical battery. For a long time galvanoscopes were the only instruments made use of. The employment of the galvanometer, properly so-called, has been possible only since the time when an agreement was reached with regard to electric units.

The first medical galvanometers, constructed by Gaiffe, were based upon the principle of Nobili's multiplier.

Let us recall Oersted's experiment. When a galvanic current passes through a wire situated in the plane of the magnetic meridian and in the neighborhood of a magnetic needle which is movable in a horizontal plane, the needle is deflected and tends to place itself at right-angles to the direction of the current.

Ampère has compared the electric current to a man lying on his back and looking at the needle while the electric current passes through him from his feet or his head. While the current is passing, the north pole (N.) of the needle is always deflected toward the man's left hand. We can make use of this law to determine the direction of the current in practice.

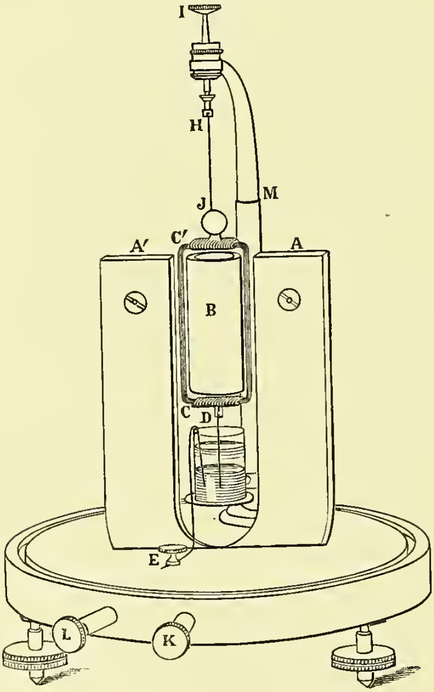
Schweigger increased the effect produced upon the needle by passing the current through a wire covered with silk and wound upon a frame of wood, ivory, or, still better, of copper. Lastly, Nobili replaced the single movable needle by two magnetic needles connected with each other by a piece of metal and arranged parallel to each other with their opposite poles adjoining (*i. e.*, with the north pole of one next the south of the other). These needles represent an astatic system. One of the needles being more strongly magnetized than the other, the system is hung by a thread of raw silk, and, while one needle is surrounded by the multiplier, the other is placed outside of the latter and turns upon a dial so as to indicate the deflections taking place in the system during the passage of a current through the multiplier. The amplitude of the deviation depends upon the intensity of the current.

It is by the aid of a system of this kind that there have been constructed medical galvanometers empirically graduated in milliampères. By giving the frame which supports the wire coils a certain curvature it is possible to make the divisions of a uniform size. This form of galvanometer, however, is for various reasons being gradually abandoned. It is influenced by the magnetic masses which are present in all our modern houses. Moreover, this galvanometer is not graduated so as to admit of the employment of very intense currents, which are now in very frequent use.

The new Gaiffe galvanometers start from the galvanometer of Despres and d'Arsonval. This latter instrument (Fig. 54) is based upon the reciprocal action of a magnet and a current. It comprises a powerful horseshoe magnet, A A′, having its axis vertical, and between its branches a tube of soft iron, B, which is fixed like the magnet, and which, becoming magnetized under the influence of the latter, concentrates the lines of force of the magnetic field upon the coil. Within the double magnetic field thus formed moves a frame wound with an insulated copper wire. This frame is suspended by fine silver wire, which itself is hung from an upright. A thumb-screw enables us to raise the frame and to put it in the right position with regard to the magnetic field. A mirror, immovably fixed to the frame, enables us to read the deflection by the mirror method. By projecting upon this mirror a ray of light in such a way that it is reflected upon a scale placed at a distance upon the wall of the room, the slightest deflections of the frame become apparent. Below, this frame has a platinum wire which dips into a cup containing

mercury, above which is a layer of water containing potassium cyanide. One of the ends of the wire wound upon the frame is attached to the suspending wire, J H, and is thus in electrical contact with the upright, M, and the terminal, K. The platinum wire, dipping into the mercury, puts the other end of the wire forming the movable frame in contact with the terminal, L, by means of the screw, E. The current to be measured, entering through K, ascends along the upright, M, descends through the suspending wire, H J, passes through the

FIG. 54.



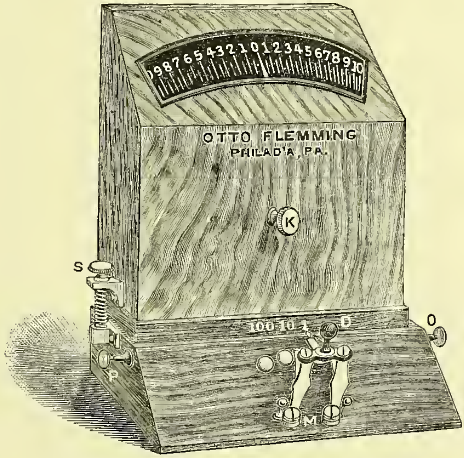
frame, C C, and leaves the latter by D, to end in the screw, E, and the terminal, L. The silver wire, H J, is about 0.05 mm. in diameter. It serves at once as a conductor of the current, as an axis of rotation for the coil-frame, and by its torsion as a spring antagonizes the force which deflects the frame. Hence the torsion may be used to measure this force.

This instrument cannot be influenced by terrestrial magnetism nor by magnetic bodies in the vicinity. It is furthermore aperiodic and

instantaneous, so that when traversed by a current the movable conductor takes its position of equilibrium at once without any oscillation. And, lastly, it is very sensitive.

[In Flemming's vertical milliampèremeter the scale is divided into ten units from zero in either direction (Fig. 55). When the double switch, M, at the base of the instrument points to the figure 1 in front of it, the figures of the scale indicate a milliampère each. If this switch be moved to button 10, the scale-reading is to be multiplied ten times. If it points to 100, the scale-reading is to be multiplied one hundred times. Thus, if the switch points to 1 and the needle indicates 3 on the scale, there is a current of three milliampères in the circuit; if the switch points to 10 and the needle to 3,

FIG. 55.



Flemming's Vertical Milliampèremeter.

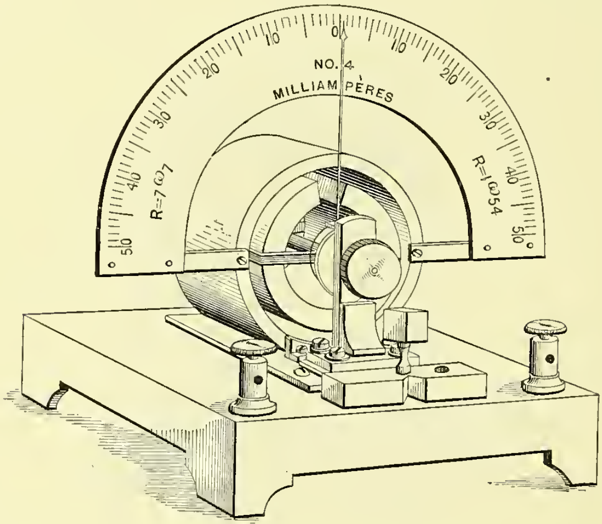
there are thirty milliampères; if the switch points to 100 and the needle to 3, there are three hundred milliampères. When using a current of less than ten milliampères, therefore, the switch, M, should be placed on button 1; when less than one hundred are to be used, it should point to 10, and when over one hundred, it should point to 100. Before turning on the current always be sure that the needle swings perfectly freely.—ED.]

In another instrument, bearing the name of d'Arsonval, the mass of soft iron of the d'Arsonval galvanometer is suppressed. The coil is mounted upon a steel axle, the ends of which are highly polished and revolve in caps of hard stone, while two spiral springs,

made of some non-magnetic metal, serve at once to bring the coil back to the zero-point and to conduct the current.

The galvanometers thus obtained are sensitive, aperiodic, and have a scale with uniform divisions. Hence, different models are made. The first two are small, portable, and must be laid flat when used. The third (Fig. 56) is large and with a vertical dial; it is mainly intended for laboratory experiments. During the whole time that the current is being administered one ought to be able to consult the galvanometer and to know the intensity of the current used without having to make any calculation.

FIG. 56.



It is, moreover, necessary when we are using the continuous current, to know the quantity of electricity that has been employed during the sitting.

If the current maintained the same intensity all the time, the quantity of electricity used in any time whatever would be known from one of the formulæ already given, namely, $Q = I t$ (where t is the number of seconds); but the external resistance being variable during the course of the same operation, a calculation of this sort is almost impossible. Practically, it is rendered superfluous by the use of the voltameter.

This instrument is a happy application of Faraday's laws of electrolysis. Let us recall these laws.

1. The electrolytic action is independent of the relative positions of the battery and of the electrolyte. Hence the voltameter may be introduced at any point whatever of the external circuit which includes some portion of the body.

2. The amount of electrolyte decomposed is proportional to the quantity of electricity which passes through the circuit. A coulomb always decomposes the same amount of water; it, consequently, sets free a definite known mass of hydrogen. As there is the same number of coulombs passing through all portions of the circuit at the same time, all the chemical actions which are produced during the same time in different parts of the circuit are proportional to the electro-chemical equivalents of the electrolytes. This law admits of no exception.

Hence, every time that the same volume of gas is produced in the voltameter, the chemical work and the quantity of electricity expended will be determined. You will nevertheless observe that we do not in this way get a measure of the total energy employed.

It is important that the reader should be made to understand the sort of indication that the voltameter furnishes.

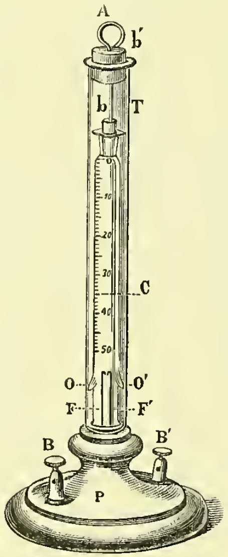
Suppose that we introduce into a circuit a human body so as to send the current continuously through the latter, and that with n cells we obtain a current, the intensity of which is I. Let us now place in the circuit a voltameter, everything else remaining the same. By so doing we shall increase the external resistance and the work. In order that the current shall maintain the same intensity, I, we must make use of a number of cells, n', greater than n. The electrical energy developed will become n'EIt, which is greater than nEIt. This increase in the energy will correspond to the electrolysis produced in the voltameter; it will afford a proportionate measure of the work accomplished in the remainder of the circuit—that is to say, in the body—by a current of an intensity, I, during the time, t, or, if you will, a measure of the quantity of electricity which during this interval of time passes through all parts of the circuit.

Gaiffe's voltameter (Fig. 57) is composed of two concentric glass tubes, one of which (C) in the centre surrounds the platinum electrodes, and is graduated so as to serve for the collection and measurement of the mixed gases (H and O) evolved. The other tube (T) is a reservoir for the liquid. The two tubes communicate by means of the little tubes (o o′). After each measurement, the only thing that we have to do, in order to fill the central tube again with liquid, is

to lift the stopper (b) of the latter by means of the ring (A). Formerly, this central tube was divided into cubic centimetres.

Boudet, of Paris, has drawn up a table which shows at once, for sittings lasting ten minutes, the quantities of electricity that correspond to the different volumes of gas which accumulate in the voltameter. Gaiffe has also made the scale read coulombs directly, and has given to the instrument the name of coulombmeter. Each division, which is divided into tenths, is equal to 0.1740844 c.cm., and represents, at a temperature of 0° C. and a pressure of 76 c.cm., a work of one ampère per second, *i. e.*, of a coulomb. The galvanometer and the coulombmeter are, it will be seen, the two most indispensable complements of galvanic batteries.

Fig. 57.



The instruments designed for measuring resistances are of less practical utility. They may, however, fulfil certain important purposes.

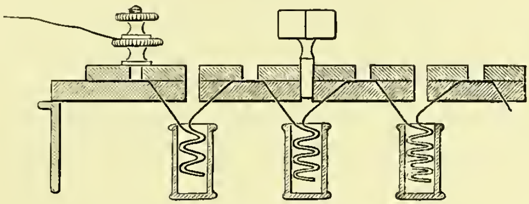
In general, we make use in practice of resistance-coils or rheostats, formed of coils of German-silver wire insulated with silk or paraffin, and so arranged that one or more of them can be intercalated in the circuit, so as to add to the latter a known resistance, varying from 1 to 40,000 ohms (Fig. 58).

In Gaiffe's medical rheostat (Fig. 59) all that we have to do is to unscrew one of the buttons of the metallic circuit attached to the

frame of the box in order to make the current pass through the corresponding coil.

The same instrument is used to measure the resistance of any part whatever of the human body under determinate conditions, or to graduate the intensity of the current by progressively changing the resistance. In the former case we operate by what is called the

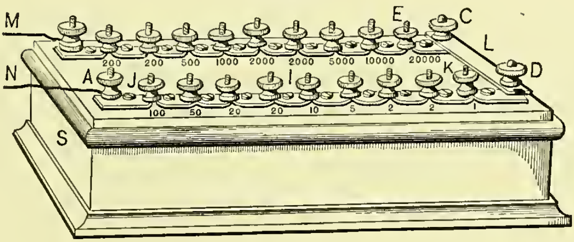
FIG. 58.



substitution-method. After having observed, by means of the galvanometer, the intensity of the current when passing through the body or a part of it, we substitute for this resistance a rheostat, the resistance in which we vary until the galvanometer indicates the same current-intensity as before. The resistance marked upon the rheostat gives the value sought for.

The rheostat is principally used to graduate the current in a gentle, progressive manner, a thing which is indispensable in applications made to certain regions, notably the head.

FIG. 59.



In certain cases we may make use of a liquid rheostat. This little instrument allows of the passage of a current through a column of liquid of variable length. There are also other rheostats which act by graduating the current in certain special forms of apparatus.

Before ending the physical part of our study of the galvanic current, we must consider the question of the density of the current.

We have already spoken of electrical density in the part of our

discourse relating to what is called static electricity. This term, when applied to the galvanic current, expresses the ratio between the intensity of the current and the size of a cross-section of the conductor. Practically, the question of the density of a current is of as much importance as that of intensity. It has been well treated of by Boudet, of Paris, whose works upon this subject will serve as our main guide.

In electro-therapeutic applications the circuit is composed, first, of conducting-wires; second, of the rheophoric plates or pads placed in contact with the skin, and, lastly, of some part of the body. The density of the current consequently varies at each of these points of the circuit. Upon the surface of the skin, which is a sensitive surface, the density should be such that during the entire period of the sitting the patient should feel no pain of any account. It is furthermore necessary that there should be no possibility of the production of an alteration in the integument, such as might take place without pain in cases of cutaneous anæsthesia.

We infer from this important law that the surface of the rheophore-plates ought to be in proportion to the intensity of the current.

At the point of contact of the rheophores with the skin the section of the circuit is measured by the active surface of the rheophore-plate. Calculation shows that, the intensity of the current being equal, the density varies considerably, according as we work with a plate having a large surface or with a small pad. The following example of this is given by Boudet, of Paris:

If a patient is immersed in a bath in the water of which dips one of the poles of the circuit, and if we apply to the part not immersed a plate having a surface of 500 square centimetres, we shall get with a battery of 20 Gaiffe cells a current of about 25 milliampères, and a current-density of 0.05 milliampère for each square centimetre of surface. If we use a pad 2.5 centimetres in diameter, and the conditions are otherwise the same, it will be necessary, in order to get the same intensity of current, to use forty-four cells in place of twenty, and the density will increase to 5 milliampères for each square centimetre, *i. e.*, it will become a hundred times as great. Under these conditions an intolerable pain will be produced, and if the application should be kept up the skin would soon suffer great injury.

If we consider what has taken place in this experiment, we shall see that the diminution in size of the surface of the rheophore pro-

duces an increase in the resistance, which has to be overcome by multiplying the number of cells.

The density for the unit of surface increases in an enormous ratio, although the quantity of electricity passing through the circuit does not vary, as the intensity of the current remains the same.

It will be necessary, therefore, in order to avoid accidents of any sort or pain, to be satisfied with a current of weak intensity when we are using a rheophore having a small surface.

From this we see that in order to send a large quantity of electricity into the body, it is indispensable that we should make a proportional increase in the size of the surface of the rheophore plate.

In practice, unfortunately, we cannot have a unit of density. We must be satisfied with the knowledge that the density ought to be diminished in proportion as the intensity of the current which is used becomes greater.

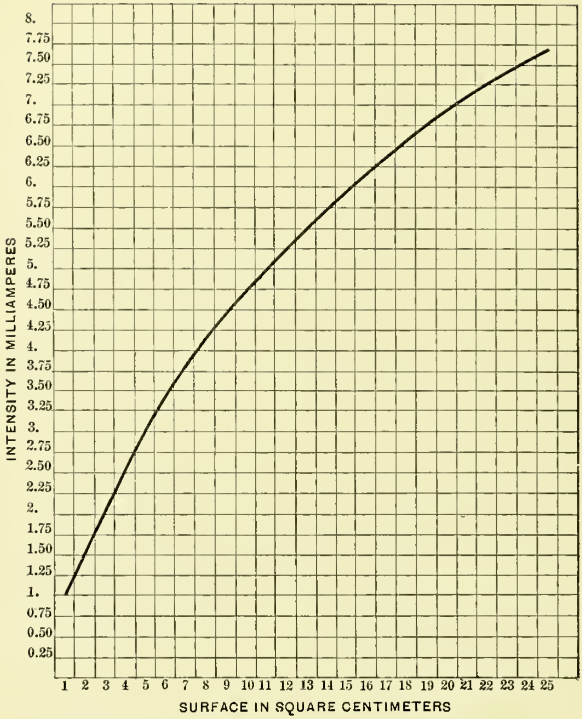
But we may seek to determine experimentally the value which can be given to the density by employing rheophores of different areas, with variable current intensities. This is what Boudet, of Paris, has done for currents from 1 to 25 milliampères, applied for ten minutes each. This work might be carried out, also, for currents of the great intensities now used.

The mean values obtained by this observer are indicated in the plates, under the form of geometrical curves (Figs. 60 and 61). By means of these plates we can ascertain the current intensity which we can employ with rheophores of known area when used by unipolar application. The plate indicates the surface of the active rheophore; and it shows what this surface should be for any given current intensity which we propose to obtain. We see, for instance, that in order to use, without danger, a current intensity of 25 milliampères, we should use a rheophore the surface of which is 500 square centimetres.

It seems to me that in general the areas for the rheophores found by Boudet, of Paris, are a little exaggerated. It is a question, to be sure, of averages, and we know that the tolerance for electrical density may vary with the individual and also with the region of the application. We may say, however, that it is almost always easy to make a current of 25 milliampères endurable when using rheophores of an appreciably smaller area, *i. e.*, of about 180 to 200 square centimetres.

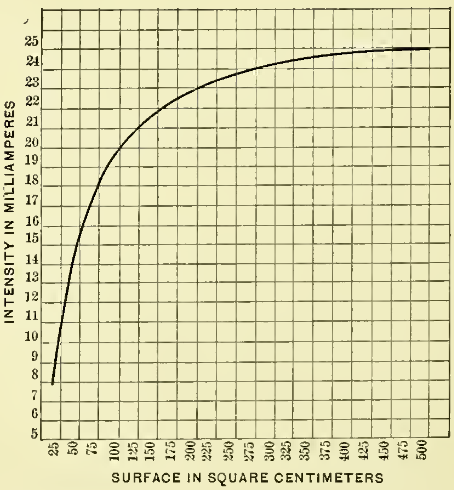
Induction. The third source of electrical energy to which we have

FIG. 60.



Curve indicating densities that can be practically employed.

FIG. 61.



Curve indicating the densities that are practically applicable.

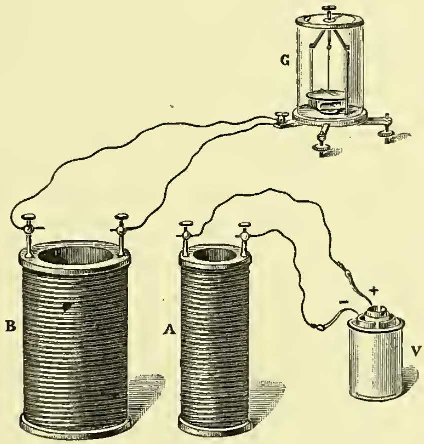
recourse is *induction*. We denote by induction currents or induced currents those which are produced by the physical action to which other currents or to which magnets give rise.

Before describing an induction apparatus it seems indispensable to recall the general facts regarding induction.

We owe our knowledge of induction to Faraday (1831), and this is the reason why the use of induced currents for medical purposes bears the name of faradization.

Let us, in the first place, consider the action which a circuit traversed by a current exerts upon a neighboring circuit. Suppose we place alongside of a conducting wire connected with a battery another

FIG. 62.



circuit, near the former but not touching it, and containing a galvanometer in its course (Fig. 62). While a uniform galvanic current is passing through the first wire nothing in particular shows itself in the second. But if we interrupt the galvanic circuit, we observe at once a deflection of the galvanometer-needle, which then returns to the zero of the scale. Now, when we re-establish the galvanic current—*i. e.*, make a closure (C)[1] of the circuit—the galvanometer-needle is deflected once more, but now in the opposite direction and to a less degree than before, and then it again returns to zero.

These facts show that at the opening of the galvanic circuit a

[1] In the nomenclature of electrical reactions the translator has replaced the French abbreviations F (fermetuse), N (negative), P (positive), and C (contraction), by C (closure), Ca (cathode), An (anode), and Cl (clonus), which are usually employed in this country.

current is produced in the second wire. This is denoted by the name of the induced current. From the galvanometer we see that this induced current is in the same direction as the galvanic or primary current, but of short duration.

These facts prove, furthermore, that at the closure of the primary another induced current is produced, but in the opposite direction. This closure current is apparently weaker. We shall, however, see later that these two induced currents are equal in quantity, but that the opening form of variation is more rapid than that of closing.

We must then distinguish an inducing current or inducing agent, and two induced currents, namely (1) the opening or direct induced current, and (2) the closing or inverse induced current.

By means of some very simple apparatus we demonstrate the following propositions :

Whenever the primary current is diminishing in intensity or receding from the secondary circuit, the current in the latter circuit is in the same direction as when the primary circuit is opened, *i. e.*, the induced current is said to be *direct.*

On the other hand, if the primary current increases in intensity or approaches the secondary circuit, the induced current in the latter is in the same direction as when the primary circuit is closed, *i. e.*, *inverse.*

The inductive action is at a maximum when the wires are parallel ; it becomes zero at the instant when the wires cross each at right-angles.

A third circuit placed alongside of the second is likewise influenced, according to the same laws, at the moment when the induced current is produced or interrupted in the second circuit. We may, therefore, have induced currents of the first order, second order, etc. In practice we make use only of induced currents of the first order.

Faraday has likewise observed that induced currents are set up in the inducing circuit itself at the opening or closure of the current. This is the phenomenon constituting self-induction. These currents are called *intra-currents.*

The opening, or direct, intra-current is added to the battery current and hence reinforces it, and consequently reinforces, too, the inductive action. The closing intra-current is weak for various reasons. The variation produced at the closure is slower than that produced at the opening, and, as the current is in the opposite direction

to that of the battery current, it tends to diminish the action of the latter.

The intra-currents are of little importance when the wires are straight, even if the latter are quite long, and this is the case when we make interruptions of the current during the treatment of a patient. The intra-currents, on the other hand, become strong when the circuit is wound in the form of a helix. In this case induction of one spiral by another takes place.

Whatever be the rapidity with which the electric fluid traverses the conducting-wire, the first spiral when reached by the fluid causes induction in the second, the second causes induction in the third, and so on. The same takes place when the current stops ; the current has come to a stop in one spiral while it is still passing in those which follow. We give the name of *extra-currents* to those currents produced by the induction of one spiral by another. They behave like the intra-currents, of which they form only a special case.

It is to take advantage of this arrangement, which enables us to reinforce the inductive action, that we wind the wires of the induction apparatus, covered by some insulating substance, either upon the same or upon different spools, which can be placed one within the other.

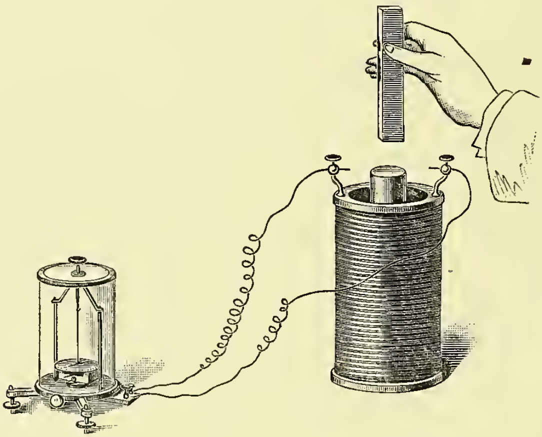
Suppose that we place in the centre of a spool a bundle of soft iron wires. Now if we pass a current through the circuit of this spool, we shall see that during the passage of the current the iron core is magnetized, mutually attractive. When we break the current the demagnetization is nearly instantaneous. This action gives rise, in the circuit upon the spool, to an induced current having the same direction as the opening extra-current which it reinforces.

The soft iron then thus placed in the centre of the spool has the important property of reinforcing the inducing current and consequently the induced current also. This property is utilized in most of the apparatus. In some it serves as a means of graduating the extra-currents and induced currents, for the action of the soft iron can be annulled by interposing in the magnetic field of the coil a metallic cylinder as a shield, which then, as is readily seen, can be used as a graduator.

Finally, in order to finish the statements regarding the principles of induction, we must recall to your mind the fact that magnets act in the same way as solenoids, and that they can consequently be made use of to produce induced currents. The way in which the soft iron

was in the instance just cited magnetized and demagnetized has already proved this fact to you. If we connect with a galvanometer an insulated coil, in the centre of which we may place a piece of soft iron to reinforce its action, we have only to approximate a magnet to the coil or withdraw it from the latter in order to produce a current (Fig. 63). The current is inverse when the magnet is brought near, direct when the magnet is made to recede.

FIG. 63.



So, too, when we make a magnetic pole or when we increase the intensity of a magnetic pole already made, the pole so made or so altered acts in the same way as a pole which we approximate to a coil.

This inductive action is at its maximum when the axis of the magnet and that of the coil coincide.

If we denote by the same general name of magnetic field the sphere of action of a current and a magnet, all the phenomena of induction follow a general law enunciated by the Russian physicist, Lenz.

All these phenomena, in fact, have this feature in common, that they correspond to a modification of the magnetic field in which a secondary, or induced, circuit is found, this modification being due either to exterior currents or magnets, or to the current which is passing through the circuit itself. Lenz's law, or rule, relates to the direction of the secondary current, and may be expressed as follows:

The direction of the secondary current is always one which, by its

electro-magnetic action, tends to oppose the act to which it was due, *e. g.*, the relative motive of the magnet and coil.

The facts regarding induction may be summed up in a table which we borrow from Hospitalier.

	Inverse induced current produced by	Direct induced current produced by
Inducing agent	A current when it is being brought nearer, when it begins, when it is increasing in intensity.	A current when it is made to recede, when it stops, when it is diminishing in intensity.
	A magnet when it is being brought nearer, when its intensity is being increased.	A magnet when it is made to recede, when its intensity is being diminished.

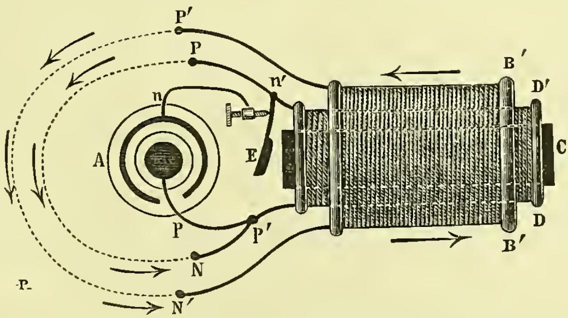
All this may be summed up briefly as follows:

1. A decrease in the number of lines of force which pass through a circuit induces a *direct* current in the circuit; while an increase in the number of lines of force induces an *inverse* current.

2. The total induced electromotive force throughout a closed circuit is equal to the rate of decrease in the number of lines of force which pass through the circuit.

These principles will be sufficient to enable us to comprehend the description of various forms of induction apparatus, and to appreciate the properties of the latter. However varied in form these appliances may be, they are all derived from the same type, *i. e.*, that afforded by the Ruhmkorff coil. We shall consider the parts of an analogous apparatus to which all the others may be referred.

FIG. 64.



The subjoined schematic plan (Fig. 64) shows how the primary and the secondary coils are arranged, and in what way the former is connected with the battery. This is of low electromotive force, and

is connected with the primary circuit or inducing coil (B) by a wire which is quite large and quite short, so as not to offer a useless resistance to the passage of the current. In the axis of the coil is a bar of soft iron, or, still better, a bundle of iron wires (C), which lessens the delay in the production of magnetization and demagnetization observed when a single bar is used. This soft-iron core in the inducing coil has several uses. Among other things, it enables us to produce automatic interruptions in the apparatus, by means of an arrangement due to Neef (of Frankfort), and represented here in its simplest form (E). The second, or secondary coil, is made with a finer and longer wire. It forms a circuit which is completed by the lead wires attached at P′ and N′. It is at these latter points that we get our induced current. Lastly, the wire of the primary, or inducing coil, is double at the ends, so that, while connected only intermittently with the battery, it can also be completed at P and N by lead wires, representing a derived circuit which can be kept permanently open or closed. The terminals P and N are used for collecting the extra-currents.

The physical phenomena produced are quite complex, but are easy to understand.

At the moment when the circuit is closed by the spring of the interrupter (E) resting upon the point (n') which establishes contact between the circuit and the battery-wire and a connection between the coil and the battery, we get a commencing current. There is consequently produced in the secondary coil an inverse induced current, and in the primary coil itself an inverse extra-current. At the same time the soft iron becomes magnetized, and thus we have a magnetic field quickly developed. This action determines an inverse induced current in the two coils, or, in simpler terms, produces a reinforcement of the inductive action.

But as soon as the bundle of soft-iron wires becomes magnetized it attracts the mass E, and draws it away from n', and consequently the circuit becomes open.

This opening of the circuit produces an interruption of the current, and consequently in the secondary wire a direct induced current and in the primary a direct extra-current. At the same time the demagnetization of the iron core produces the effect of a rapidly receding magnet, which determines a still further reinforcement of the inductive action, *i. e.*, of the direct induced current and the direct extra-current.

Properties of Induced Currents. It is not enough to know the manner in which an induction apparatus is constructed, it is also necessary to have some ideas in regard to the properties of induced currents.

These currents, being the result of an inductive effect exerted by the primary coil, are dependent partly upon this coil and partly upon the conditions set up in the secondary coil.

Other things being equal, the intensity of the induced current varies with that of the inducing current, and with the length of the inducing circuit. As has been cited, the induced currents are alternating, *i. e.*, alternately inverse and direct. They are the result of the variable stage of the primary current at the instant when it is being established, and when it comes to a stop. This current starts from zero, increases until it reaches a permanent state, and then, starting from this point, decreases until it becomes once more zero.

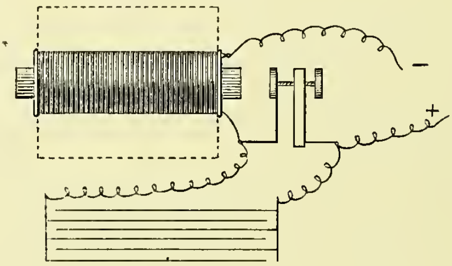
When the interruptions are very frequent, the breaking of the current is effected before the end of the variation, *i. e.*, before the permanent state is established, so that too frequent interruptions impair the inductive effects.

The direct and inverse currents upon the same secondary coil represent the putting into action of an equal quantity of electricity; but the currents, considered in relation to each other, have neither the same intensity nor the same electromotive force. In fact, the difference of potential which is established in the secondary coil, and hence, also, the intensity of the current, vary in inverse ratio to the time of the inducing action. Now, the opening variation in the primary coil being shorter than the variation of closing, the direct induced current corresponding to the opening of the circuit has a higher electromotive force and intensity than has the inverse current, which is produced by the closure.

The causes of the difference in the duration of the variable state in the primary coil are several. The prolongation of the variation at the closure of the circuit appears to be due simply to the production of the inverse extra-current. The phenomena at the opening of the circuit are more complex. The direct extra-current which makes its appearance at this instant gives rise to a spark which tends to prolong the variation, and consequently to diminish the difference between the duration of the two variations. The current diminishes before coming to a stop, and the soft iron becomes demagnetized less

suddenly. These causes of impairment of the inductive action may be, to a great extent, avoided by means of an arrangement devised by Fizeau (1853). It consists in connecting this point of the circuit on both sides of the interrupter with a tinfoil condenser, the function of which is to draw off the extra-current and to diminish the spark (Fig. 65).

Fig. 65.



The medical forms of apparatus are not provided with this condenser.

Let us now consider the influence exerted by the construction and location of the secondary coil, without, however, going into the questions of pure physics which are raised by this rather difficult subject.

The induced current produced by a given inducing current, presenting determinate periods of variation, depends, from a practical point of view, mainly upon the length of the wire in the secondary coil.

Under the conditions under which the forms of apparatus used in medicine are constructed, the predominant property of coils with a coarse, short wire is quantity. The current-strength in this case is high, but the electromotive force is comparatively weak. In coils made with a finer wire, and containing consequently a greater number of turns, the property which gets to be predominant is the difference in potential between the terminals or the electromotive force.

The current-strength in this case is comparatively small. In practice, therefore, we ought to choose coils with long, fine wire in all cases in which we shall require to produce effects which are dependent upon electromotive force; and, on the other hand, we shall give the preference to coils with a coarse wire.

In general, in medical apparatus the wire of the primary coil is from 1.5 to 2.0 mm. in diameter and from 6 to 35 metres long, and

that of the secondary coil has a diameter of about 0.16 mm. and a length of 1000 to 1800 metres. But we shall see that certain forms of apparatus enable us to use coils made with wires of various diameters and a greater or less length.

Lastly, we may add that the situation of the coil may serve as a means of graduating the current, since the inductive effects diminish progressively as the coil conveying the secondary current is carried further away from the primary coil; and are, on the other hand, at their maximum when one coil covers the other.

We have seen that the two extremities of the wire of the secondary coil correspond to the two metal terminals, P′, N′ (Fig. 64). These are the terminals of the coil. If we consider both induced currents, namely, that produced at the closure and that produced at the opening of the circuit, each of the terminals is alternately a positive and a negative pole; but in most medical and physiological applications the closing induced current can be ignored for reasons that we have now become acquainted with.

Practically, then, we take into account only the breaking current. When a finger is applied at each terminal the pole which provokes the most painful sensation is the negative one.

Induced currents, except for their alternation and the brevity of their duration, obey the general laws governing other currents, and are capable of producing the same physical effects as the latter. To show this we need only commute the direction of the inverse currents so as to get them all together in the same direction, as we do in the case of dynamo-electric machines. It can then be seen that induced currents possess the same chemical properties as do the primary currents. As to calorific effects, this is not necessary in order to establish the fact of their production, since the quantity of electric energy in a circuit is independent of the direction of the current.

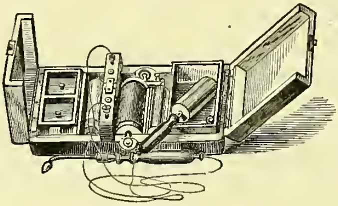
From a physiological point of view, an induced current as its specific characteristic, presents great differences of potential, which are associated with a comparative weak current strength, a condition which is very different from the characters presented by the primary current. We may also add that, as induced currents have a very short duration, they cannot give rise to reactions which, in a normal or pathological state, require excitation lasting for a certain time.

In practice we do not measure induced currents. We concern ourselves only with the number of interruptions, which in apparatus of the better make can be varied at will, so as to have a defi-

nite number of shocks, rendered more or less energetic by means of various methods of graduation. Hence, the Congress of Electricians, held in 1881, has recommended the use of a normal coil, which, when set in action by a current of constant intensity, will enable physiologists and physicians to put themselves under conditions that are always identical, and thus to have results that are comparable with one another. Unfortunately, manufacturers have paid no heed to this advice. Each one always tries to show the difference between himself and the rest by the differing character of his model and theirs.

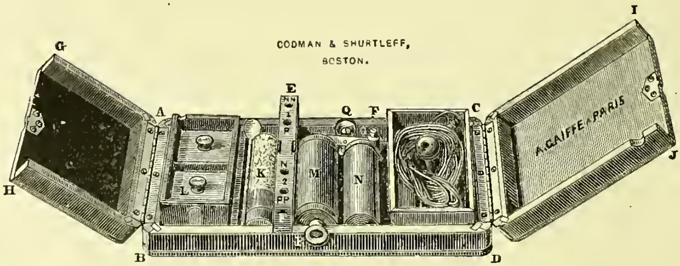
If for the precise experiments of physiology we should wish to estimate the energy of induced currents, we might make the calculation by sending a discharge into a ballistic galvanometer and comparing the effect with that emitted by a condenser of known capacity.

FIG. 66.



Gaiffe's bisulphate of mercury pocket battery.

FIG. 67.



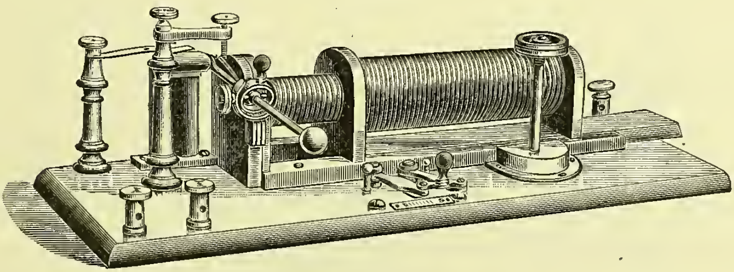
The kinds of induction apparatus used in medicine are too numerous for us to be able to describe all of them. They differ mainly in their size, in the way in which the interruptions are made, and in the method of regulating them.

In the small forms of apparatus and in some of medium size, constructed mainly with the view of being portable and not very

costly, the interruptions are obtained by means of a Neef vibrator, and in general there is but one coil of fine wire, which is fixed, and which covers the inducing-coil. These small forms of apparatus are run by a bisulphate of mercury tray battery (Figs. 66 and 67). In these we can to a certain degree modify the number of interruptions. Moreover, the regulation of the intensity of the currents is obtained by means of a brass cylinder, which moves back and forth parallel to the axis of the apparatus between the core and the inducing-coil. When we wish to utilize the effects of a coil with a short and coarse wire there are generally special terminals which enable us to collect the extra-currents of the inducing-coil.

The medium and large-sized models have the advantage of possessing a vibrator which can give a variable number of interruptions and of having multiple coils, usually mounted on a sliding-stand, analogous to those of Siemens and Halske's model, used for the first time by Du Bois-Reymond. When these forms of apparatus occupy a stationary position in a physician's office an outside battery is used to run them; but some are arranged in a portable box. In America such apparatus as those illustrated in Figs. 68 and 69 are commonly employed.

Fig. 68.

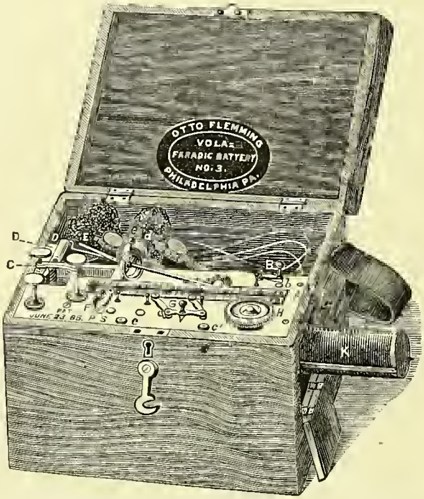


Flemming's Du Bois-Reymond induction-coil, with or without interchangeable multiple coils, rapid and slow interrupters adjustable to variable rhythms to an absolute zero; also provided with rack and pinion device for governing current strength, commutator, and division-scales. May be run by two Axo cells or one Grenet bottle-cell.

In Trouvé's clock-work interrupter (Fig. 70) a cylinder divided into twenty-five parts in the direction of its length is moved by clockwork, the rapidity of the movement being governed by a fly-wheel regulator, so that the cylinder may be made to describe any desired number of revolutions a second. Each portion of the cylinder is provided with a certain number of frets or pegs, the number of which increases regularly, forming a series of integers. There is a

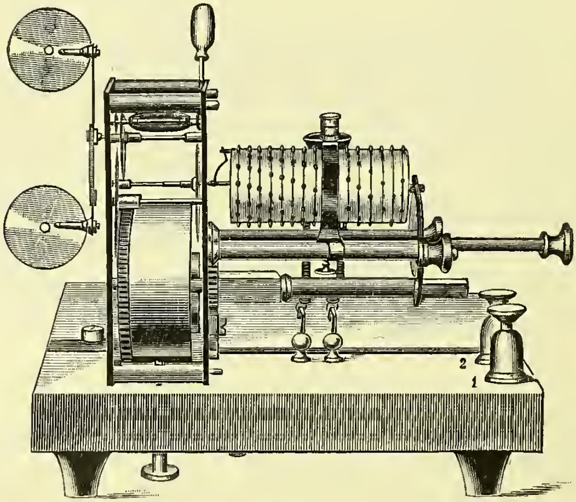
style which can at will be moved parallel to the axis of the cylinder, and which can thus be placed in contact with each series of frets in

Fig. 69.



Du Bois-Reymond induction-battery, the same as Fig. 68, in portable form, with or without interchangeable multiple coils.

Fig. 70.



succession. The current is interrupted as many times as there are frets.

Many other systems have been proposed for producing an interruption in the inducing-current. We will mention, in addition to those that we have described, only the use of tuning-forks, whose specific vibrations are kept up by means of an electro-magnet, placed in series with the primary coil, or actuated by a current furnished by a special battery. For precise experiments, electric tuning-forks have the great advantage of furnishing interruptions which are absolutely regular, whatever their rapidity may be; but they can only be used in cases in which we wish to have very rapid induced currents. Boudet, of Paris, made use of two tuning-forks, one having 60 and the other 215 double vibrations a second.

The forms of apparatus with superimposed coils, which, as we have seen, are graduated by means of a brass cylinder, have the disadvantage of not giving an absolute zero. They cannot, therefore, be utilized for physiological researches, which often require the use of currents having a minimum energy. Hence, what are called the sliding-stand forms of apparatus have been devised, which enable us so to graduate the induced currents by means of the greater or less degree of separation of the two coils—primary and secondary.

These latter forms of apparatus offer the additional advantage of enabling us to take the ordinary secondary coil away completely, and to replace it by another of the same diameter, but having a wire differing from the first coil in length and thickness.

It is to Tripier that we owe the first medical apparatus of this sort.

Tripier's large apparatus, constructed by Gaiffe, possesses three secondary coils; one with coarse wire, the resistance of which is about 1 ohm; a second with medium-sized wire and having a resistance of 15 ohms; and, lastly, a third with a long and slender wire, the resistance of which reaches 1300 or 1400 ohms. From what has been already stated, it can be seen that with the same inducing-coil we have in this apparatus the means of varying the tension according to the various requirements that may arise in its practical application.

There is, besides, a Tripier's apparatus which is smaller and which is inclosed, along with its generating-battery, in a portable box, although it may also be run by a battery outside (Fig. 71). The sliding-stand carries two secondary coils, one with a coarse, the other with a fine wire. To make the use of either one of two coils we have only to reverse the mechanism which supports both.

FIG. 71.

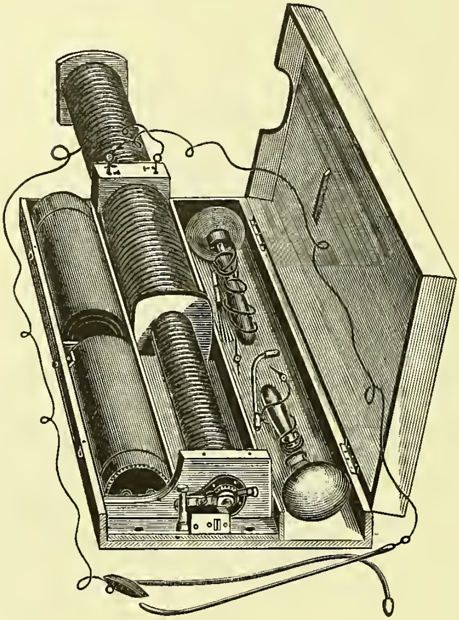
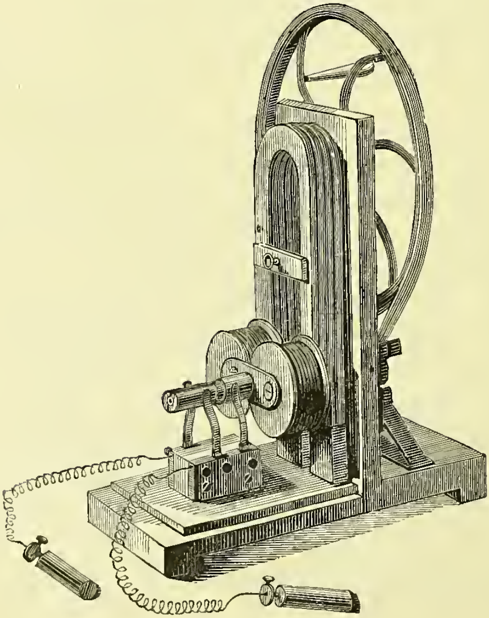


FIG. 72.



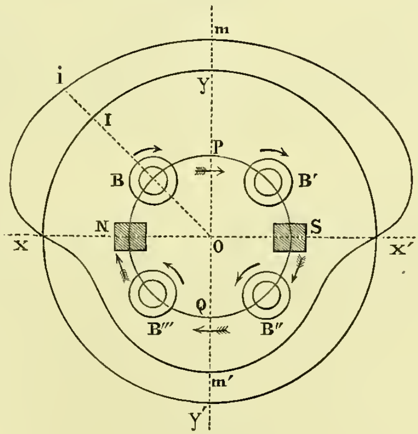
We may likewise employ the opening extra-current taken from the inducing-coil. To graduate this extra-current we connect the secondary coil with itself by means of a small wire. It then acts like a regulating-cylinder. We may, furthermore, intercalate a water-rheostat in the circuit.

The vibrators giving a variable number of interruptions, the description of which we have just given, are generally fitted to the large or medium-sized sliding-carriage form of apparatus. All manufacturers now offer apparatus of this sort of various sizes.

Formerly, before the invention of Ruhmkorff's coil, physicians ordinarily used magneto-electric machines. At the present time these are seldom used, because of the necessity of having a third person to turn the handle when they are employed. These instruments have, however, a real value, and afford in certain cases some advantages. The medical magneto-machines all start from the types furnished by those of Clarke and of Page.

In Clarke's machine (Fig. 72) an armature of two coils of wire is so arranged that it can be turned in front of the poles of a permanent fixed magnet. During the rotation of the armature the lines of force of the magnetic field are cut in such a way that currents are induced in the coils.

FIG. 73.



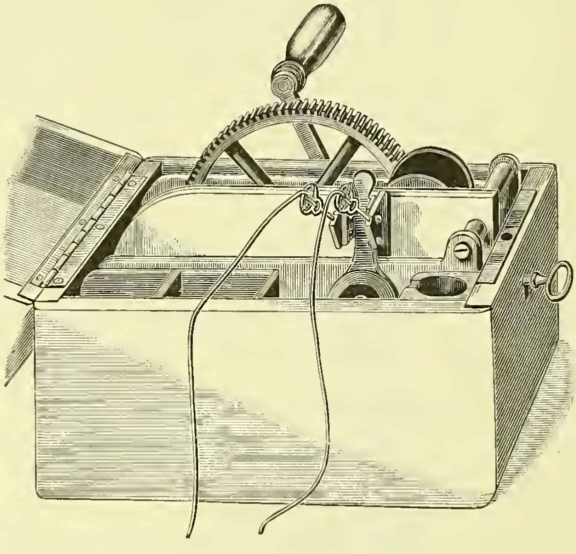
After Guriel.

Let S and N (Fig. 73) be the two poles of the magnet, and B, B′, B″, B‴ the different positions of a coil revolving about the centre, O, in the direction indicated by the feathered arrows, and suppose, for

the sake of simplifying the explanation, that when the coil is in the vicinity of one of the poles that pole alone is active.

Let us first take the coil facing N, and in the act of receding from it with a uniform motion. There will be produced in the circuit, of which the wire of the coil forms a part, a current having the direction indicated by the unfeathered arrow. The current, at first strong, will progressively diminish; but soon the coil will approach the point P, and the action of the pole S will begin to make itself felt. The pole S corresponds to a specific current having a direction opposite to that of N; but, inasmuch as the coil is approaching S, an induced current will be produced having a direction opposite to that of S, and consequently the same as that of the current first set up. The latter will be kept up, but the moment the coil passes S the current will suddenly change its direction. The same effects are reproduced for this second half of the revolution, and it can be seen that we thus obtain alternating induced currents.

Fig. 74.



A special arrangement of that part of the apparatus which collects the currents enables us either to get currents which alternate—*i. e.*, as they are given by induction—or to get currents whose direction is always the same.

In Page's machine it is the poles of the magnet that are furnished with the coils.

We may combine the two systems, as Gaiffe has done, by placing

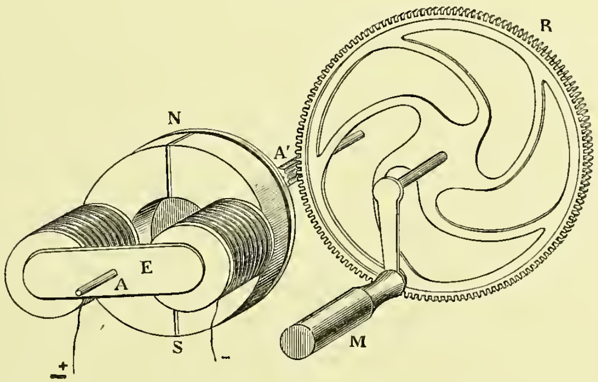
the helices both upon the armature and upon the magnet, and thus obtain an apparatus which, though of small size, has a considerable power.

The models, however, that are the most commonly employed in medicine, particularly in England and America, are all similar to the Clarke machine.

Gaiffe makes a Clarke machine which he has rendered very practical by supplying it with an appliance which serves at once as a rectifier of the direction of the current, an interrupter, and a graduator. (Fig. 74.) The graduation of the current is obtained by varying the interruption from the minimum to the maximum point of the curve of intensity of the induced current; a simple sliding of the brushes along the collector gives this result.

This apparatus, in spite of its small size, furnishes currents of

Fig. 75.



rather high electromotive power analogous to those of the induction-coil; and, furthermore, puts into action a considerable quantity of electricity, which cannot be obtained with the induction-apparatus. It also has the advantage of giving currents constant in direction.

Very recently d'Arsonval devised a new magneto-machine, capable of furnishing regularly alternating currents. This machine (Fig. 75) consists of a movable magnet revolving in front of and very near a fixed electro-magnet. The magnet, instead of being horse shoe-shaped, is circular. It is formed of several disks of steel, magnetized separately to the point of saturation and attached to one another. The two poles are at the extremities of the same diameter, NS. The magnet is mounted upon an axle, AA′, which is set in motion by means of a pinion and toothed-wheel, R. The

cores of the fixed coil, E, are the same distance apart as are the poles of the movable magnet.

During the rotation of the magnet there are produced in the coil induced currents, which change their direction with each half-revolution. These currents do not have their directions rectified, and can produce a continuous excitation, which is regularly alternating. We vary the electromotive force, and consequently the intensity, of the induced currents either by varying the rapidity of the rotation or by bringing the fixed coil more or less close to the magnet. The intensity of these currents may be represented by the ordinates of a sinusoid (the sine curve), the abscissæ representing the times; hence, these currents are sometimes called sinusoidal currents.

At present Gaiffe is working upon a machine designed for medical use, and furnishing, by means of a dynamo analogous to that used in electric motors, a sinusoidal current which it is easy to graduate.

Lastly, we will mention an apparatus devised by Dr. Fontaine-Atgier, and which he has denoted by the name of volta-gramme machine. Two coils placed opposite to each other are separated by a vibrator, which is at once a commutator and a switch. The separate parts placed in and upon the coils are too complex to be described in detail, but, in general, are so arranged that one of the coils is in the electric state exhibited by the closing form of variation, while the other is in the state exhibited by the opening form. We may then collect the direct induced currents without loss of time, so that a subcutaneous excitation is furnished; or may collect alternating currents in the opposite direction, also, without any loss of time, in which case the excitation set up presents a certain analogy with that which d'Arsonval's apparatus produces. In reality we get in this way undulatory currents, which are not absolutely continuous, and which are more like ordinary induced currents than continuous currents from a battery.

I should also point out to you that it is possible to associate the induced and galvanic currents. To apply this method, which has been used in recent years by some practitioners, we intercalate in the circuit of the secondary coil, by means of a de Watteville current-combiner, a galvanic battery like those which we make use of for producing continuous currents. When, then, we connect the positive pole of this battery with the negative pole of the induction-battery, even two cells acting in the former will produce an intense effect by adding to the tension-effects produced by the induction-apparatus a certain quantity of electricity; on the other hand, when the gal-

vanic battery is connected with the coil by poles of the same name (positive with positive), the tension-effects due to the induced current will be found to be annulled, even when only three or four cells of the battery are employed.

This method of electrization gives rise to quite complex physical conditions. According to some authors, including Boudet, of Paris, it should offer great advantages in some cases of muscular atrophy.

Animal Electro-genesis. We have borrowed from electrophysics simply those facts which it was indispensable for us to know if we wish to understand the different kinds of medical apparatus and to make use of them with some degree of precision. So, too, in taking up the second part of our subject, which relates to physiology, we shall concern ourselves only with questions which may have practical importance.

To Galvani (1786), whose celebrated experiments are well known, is attributed the discovery of neuro-muscular excitability—a discovery which is one of the most remarkable in physiology. This observer, at the same time, discovered animal electricity.

Since this epoch this important chapter of physiology has been the object of very many researches, notably on the part of Matteucci and Du Bois-Reymond (from 1840 to 1843). The experiments of this latter physiologist, owing to the conditions under which they were performed, have been more productive in the demonstration of facts.

In order to prove that animal tissues are electrogenic it was, in fact, necessary to avoid the generation of electric currents at the points of contact between these tissues and the instruments employed. Du Bois-Reymond succeeded in doing this by borrowing from J. Reynauld the idea of using non-polarizable electrodes formed of amalgamated zinc immersed in a saturated and perfectly neutral solution of zinc sulphate and applied to the tissues through the medium of a saline solution.

The first researches made in this direction revealed some interesting facts which, unfortunately, became the starting-point of very questionable theories, so that for a long time electro-physiology remained one of the most obscure branches of science. Even at present it can scarcely be regarded as more than outlined. It is, moreover, a difficult study, requiring special apparatus which has only very recently arrived at some degree of precision.

In electro-physiology it is alone of all things indispensable to work with really non-polarized electrodes and with good galva-

nometers. The electrodes used at present are those of d'Arsonval. They consist of a silver wire coated with fused chloride of silver and kept in a glass tube filled with a 1 per cent. solution of sodium chloride. It is easy to make them one's self and to give them a convenient form and size. But it is well to be warned in advance that they are sensitive to light.

We can thus in a very simple manner, by acting upon the silver serre-fines with chlorine, form electrodes suitable for seizing the tissues, and especially the muscles, directly.

Two principal divisions of electro-physiology are to be distinguished: that treating of animal electrogenesis and that treating of the action of electricity upon the organism and upon its various parts.

The former has served as the theme of a great number of theories, the result of which has been to make its history very complex and rather confused. From a practical point of view it presents only a very limited interest. The second, on the other hand, is of great importance for us, for it should serve as the foundation of all rational therapeutical applications.

We should not, however, remain indifferent to facts regarding animal electrogenesis, and a short account of it is of value, taking as a guide the interesting considerations which have been developed with respect to this subject by d'Arsonval.

The body and detached living fragments of the body are electrogenerators, *i. e.*, producers of currents.

Among the electric manifestations which take their origin from the tissues we may distinguish those which are continuous, or the *currents of rest*, and those which are momentary, or the *currents of action*.

We make the existence of these currents evident by using a frog's leg properly prepared. The sciatic nerve is carefully isolated, the skin removed, and the nerve and leg detached by division of the muscles and the bone in such a way as to have a certain length of nerve free. We thus have the galvanoscopic leg or physiological rheoscope.

If with a glass hook we turn the nerve over so as to bring its cut surface in contact with the surface of the muscle, we see that a single but energetic muscular contraction takes place; this is the fact discovered by Galvani; the leg thus prepared is at once a source of electricity and a galvanoscope. Careful study of this phenomenon shows that there is a current which passes from the body of the muscle to

the tendon as long as the muscle remains alive. The surface of the muscle is positive with relation to the section of the nerve which is negative.

The same is true of the nerve, but at this point the current is weaker. It is the sudden variation produced in the case of the preceding experiment, by contact of the cut surface of the nerve with the surface of the muscle, that determines the muscular contraction.

To show the existence of the current of action, we use two galvanoscopic legs. The nerve of the second is upon the muscular mass of the first, and at the moment when the muscle contracts by being put in contact with the extremity of this nerve, or by mechanical excitation of this nerve, a contraction is observed to take place in the second leg. Matteucci has given to this phenomenon the name of *induced contraction.*

If, on the other hand, we stimulate the nerve of a galvanoscopic leg so as to get a tetanization of the muscle, we see a great decrease take place in the current of rest. This last phenomenon constitutes Du Bois-Reymond's *negative variation.* When we study what happens upon the stimulated nerve we find that the same thing occurs. It is the sudden variation in the electric state that is the cause of the stimulation of the nerve of the second galvanoscopic leg in the experiment of induced contraction.

It is not necessary to dilate upon these well-known facts. The question which is of real importance is whether the phenomenon observed upon detached portions of an animal's body is not the consequence of the alterations which vivisections produce in living tissues. This objection has been raised by physiologists of good standing. Hence Du Bois-Reymond has attempted to demonstrate the phenomenon of a negative variation in uninjured animals and in man. This physiologist has experimented upon the arm and has shown that the current of rest diminishes at the instant that the subject experimented upon contracts his muscles. It has been remarked that under these conditions there were causes of error due to the production of currents set up by variations in the state of the skin. But it can be demonstrated that every contraction of the heart is accompanied by this same phenomenon of negative variation. This fact may be established not only for the heart of the frog or tortoise which has been exposed to view, but also for the dog's heart which has been left *in situ* and into which our chloruretted needles are plunged. A. Walher, by applying his in-

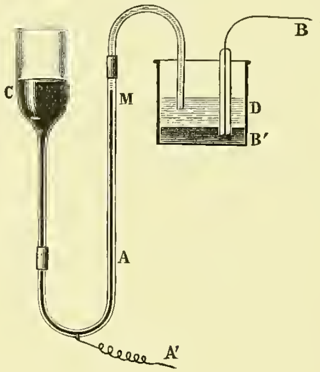
struments to the surface of the chest, has demonstrated the negative variation produced by the cardiac contraction in man.

We are then justified in supposing that the current of rest really exists and that it is not simply the result of the lesions that have been produced which render it manifest. But how should we interpret these phenomena which we have just now briefly recalled to mind?

Among the numerous theoretical explanations which have been given of these facts, we will cite only the recent and ingenious hypothesis enunciated by d'Arsonval. This hypothesis is a deduction from the interesting experiments of Lippmann upon what is called *surface-tension.*

It is admitted that the force of cohesion of the molecules of every liquid contained in a vessel develops a certain amount of

FIG. 76.

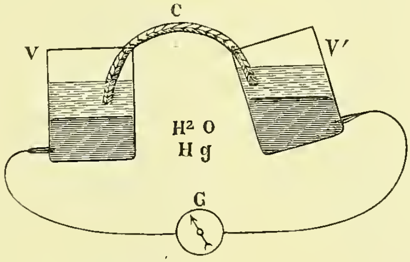


tension upon the surface of the layer of liquid. When two liquids of different density are placed in the same vessel a double tension layer is produced at the surface of contact of the two. Lippmann experimented with mercury and with water acidulated with sulphuric acid. From numerous experiments which he made he concluded that the surface-tension or capillary constant at the surface separating the two liquids is a function of the difference of electric potential of the latter. He also saw that the surface-tension and this potential difference undergo simultaneous variations, and upon the basis of these laws he has devised the electrometer which bears his name. It is worth while to point out the principle of this ingenious apparatus. A capillary tube, A (Fig. 76), communicates by

one end with the under vessel, C, containing mercury, and by the other with the vessel, B′, containing acidulated water, which lies upon a layer of mercury. The two masses of mercury are connected respectively with the platinum wires, A′ and B.

When the two wires are connected directly the potential of the two masses of mercury is the same, and the mercury always stops at the same point, M, in the capillary tube. This is not so, when, after separating the two wires, A′ and B, we impart to them a difference in potential by means of any exterior source of electricity whatever. The level of the mercury changes and now occupies a new position of equilibrium which remains absolutely constant for the same difference of potential between the wires, A′ and B.

FIG. 77.



The converse of the law which has just been enunciated, and upon which is based the capillary electrometer, is likewise established by experimental facts, and may be stated as follows:

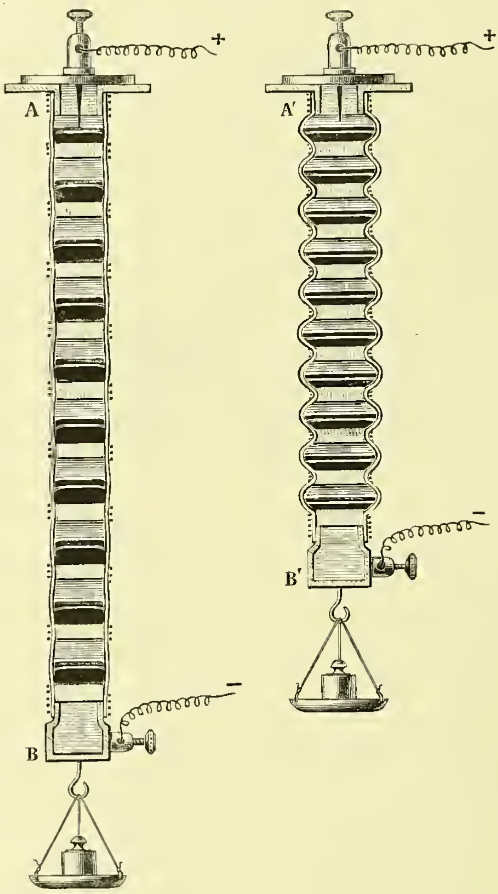
When the surface separating two liquids of different density is disturbed by mechanical means a state of electrification is created, the character of which is such that the corresponding surface-tension opposes a continuation of the movement.

We may mention one of the experiments by means of which we demonstrate this proposition. Two vessels, V and V′ (Fig. 77), each containing mercury covered with a layer of acidulated water and placed side by side, are connected by means of a wisp of cotton, C. A galvanometer, G, is connected with the masses of mercury. As long as the two vessels are kept still, no current passes through the galvanometer; but if we suddenly incline one of the vessels (V′), the needle is at once deflected and indicates the existence of a current which passes through the liquid of the tilted vessel to the vessel which has been left upright.

Starting from these experimental facts, d'Arsonval has devised a sort of artificial muscular fibre capable of giving shocks.

A caoutchouc tube (A B, Fig. 78) is divided into a series of compartments by porous disks of bamboo or of earthenware, the tube being tightly corded wherever these disks occur. Each compartment

Fig. 78.



is filled with a layer of mercury covered by a layer of acidulated water. If we hang the tube up by its upper end, and, after grasping its two ends, stretch it suddenly, we feel a shock. If we hang from B a weight which we make oscillate from above downward and back again, so as to make the apparatus take successively the forms A B and A′ B′, we get alternating currents. Finally, if after having

attached the end, B, to the centre of a diaphragm, we connect A and B with a telephone, or, better, with a microphone, the apparatus will reproduce speech.

We see, then, that mechanically produced derangements of shape, however slight and however rapid, modify the electric state; and, conversely, variations in electric state, however slight and however rapid, are accompanied by a derangement of shape.

According to d'Arsonval, we observe the same phenomena in all liquid or semi-liquid bodies, either of organic or inorganic origin, which present a surface of contact that can be distorted mechanically.

These physical properties would furnish the explanation of the physiological phenomena previously described.

The negative variation occurring simultaneously with the contraction of a striated muscle would be due to the variation in the surface-tension, and, consequently, in the electric state, which is the consequence of the internal mechanical distortion occurring in every living tissue which is undergoing a spontaneous change of shape.

Du Bois-Reymond, moreover, has shown that the negative variation can still be observed when the muscle is imprisoned in plaster.

The electric organ of fishes (the torpedo, for instance) presents a great analogy to muscle. The discharge from this organ is probably due to the same cause as is the negative variation of muscle.

Whatever may be the truth of the theoretical explanation offered by d'Arsonval, the fact of the electricity of muscles seems to be well established. This electricity is bound up with the life of the protoplasm of the cell, and should be regarded as one of the modes of transformation of the chemical energy expended in a cell which is alive—*i. e.*, in a state of nutrition.

D'Arsonval even thinks that the heat resulting from the nutritive processes is only the consequence of a second transformation. The muscle would, according to this, be an electric and not a thermic motor. In the spontaneous play of muscle-tissue the energy would first take the chemical form, under the influence of cellular nutrition, and then the mechanical derangement in shape of the protoplasm would evolve an electric energy, itself changing afterward into the form of heat.

The theoretical views enunciated by d'Arsonval cannot yet be regarded as demonstrated, but it is well to be acquainted with them, because they apply to well-established physical facts, and

they have the advantage of representing living matter as the seat of phenomena in which there is an opportunity of allowing for the transformation of the various kinds of physical energy into one another. In this living matter, in fact, we see the phenomena of mechanical energy, electric energy, and heat making their appearance, and we may say that the laws which govern these different manifestations are without doubt the same as for inorganic bodies.

We should conclude from this that the phenomena produced in living matter at the moment when physical agents, and especially the electric agent, exert their disturbing action, are of prime importance. But the study of these facts is at present complex and very obscure, for we know nothing of the relations that may exist between the different forms of vital and of physical energy. What could we say, for instance, regarding the possible relation between electric energy and what is understood in physiology by the term *neurility* or *nervous force?*

All that we can now assert is that electrical phenomena are manifested constantly during vital actions, and that electricity appears to be normally one of the agents necessary for the production of the manifestations that are called physiological.

Application of Electricity to the Body. Applied to the body electricity acts upon it differently as its mode of application creates a permanent, fixed state, such as is set up by the passage of a continuous current, or creates a variable state represented by interrupted or periodical currents.

We know already that the variable state is more particularly adapted for producing excitation of the nerves and muscles. The physiological manifestations to which it gives rise are very apparent and are comparatively easy to analyze.

The continuous flow of the galvanic current produces work which is more diffused, more deep-seated, and more difficult to grasp—one which seems to be mainly associated with chemical energy, and of which, so far, we have not been able to give a precise account.

We must likewise regard the procedure denoted by the name of the electrostatic bath as one of the means of applying electricity continuously. We will begin our description by stating the effects produced by this kind of application.

STATIC ELECTRIZATION. The body of a subject is insulated by being placed on a stool and put in communication with a static ma-

chine, or not insulated, and receiving, by means of the appliances that we shall describe, what is called the *electric wind*, is traversed by a constant current of high potential which leaves the surface of the body through the air, the latter playing the part of an external circuit.

The intensity of this current is really very slight, and yet the physiological phenomena produced by static electrization are notable.

The effects of atmospheric electricity have been known for a long time, and in the last century men began likewise to suspect the influence which static electricity exerts upon the general state of the body.

However, the methodical employment of static electricity goes back scarcely fifteen years, and we are still but imperfectly acquainted with the physiological phenomena to which it can give rise.

All observers have noticed the bristling of the hair and the cobweb sensation which spreads over the surface of the body. Many, also, agree in recognizing the modifications produced in the circulation. As early as the eighteenth century Jallabert and Sauvages had remarked the increase in rapidity of the blood-current and the acceleration of the pulse—facts which were rediscovered by Stepanow, Vigouroux, and Eulenburg. Stepanow observed that while the electrostatic bath lasted there was a more marked elevation in the sphygmographic tracing, and that the dicrotism was increased. Damian has confirmed this observation. According to this, there should be a diminution in the vascular tension, but in a patient of Charcot's, who had just been bled, the flow of blood which at first had stopped, reappeared under the influence of the electrostatic bath.

Jallabert has noted an increase in the temperature, a fact which was also remarked by Stein and Vigouroux. According to Danion, this effect belongs to only the electropositive bath, the electronegative bath producing no variation in temperature, and negative sparks causing a slight reduction of the latter.

According to the older authors, static electrization increases all the secretions. The increase effected in the perspiration is a fact that has been often observed. According to Stepanow, the sweat diminishes at the points that are being electrified and increases over the rest of the body. The same author has also observed an increase in the quantity of urine passed in the twenty-four hours. Danion observed this increase in the quantity of urine only with the negative bath.

General sensibility is certainly more or less modified, but in a manner varying according to the subject of the experiment. Most observations upon this point have been made upon sick people, and are, consequently, not adapted for giving us information as to the real physiological effects of the electrostatic bath. In a general way, the latter produces rather a sedative effect than one of excitation; sometimes it even tends to cause sleep, and it is not a rare thing to see patients overcome with sleep while still upon the insulating-stool. In this connection we must take into account the action of the ozone which is evolved in abundance in the atmosphere of the room where the machine is being worked.

A more or less marked increase in the appetite at the end of a certain number of sittings has been noticed, as well as the development of some menstrual disturbances, particularly a doubling of the number of menstrual periods.

As to the question whether there is any difference in action between the positive and the negative bath, authors have given contradictory opinions. According to Eulenburg, Benedictow, and Vigouroux, the two kinds of bath produce sensibly the same effects. On the other hand, according to Stein and Larat, the positive bath is sedative and the negative bath exciting, and we have just seen that Danion believes that certain physiological effects depend on the nature of the bath. We may add that Schliep, in studying the effects of atmospheric electricity upon the body, has found that a positive atmospheric tension produces effects of excitation, while a negative tension causes a state of marked depression.

The general phenomena observed by the electricians of the last century should attract the attention of the authors of the present day to the modifications which static electrization may effect in the general nutrition.

D'Arsonval, in studying this question, has constantly observed an increase in the respiratory combustion, independent of the effect produced by the ozone. On the other hand, Danion has demonstrated an increase in the excretion of urea in the urine, particularly after the positive bath. Static electricity, therefore, would appear to have the property of increasing the nutritive processes.

It is interesting to compare these phenomena observed in man with the influence which electricity exerts upon vegetation.

The Abbé Nolet noticed that an influx of electricity favored the development of vegetables. Then accurate experiments made with

the galvanic current have enabled Berthelot recently to establish the action of electricity upon vegetation; and analogous observations have been made by Armand Gautier.

But to confine ourselves to our subject—that is, to the effect of static electricity—we will adduce in particular the experiments made on a large scale by Spechnew. This experimenter planted here and there in wheat-fields wooden posts tipped with a metal point and representing lightning-rods, connected with the ground by a conducting-chain. In this way the surface of the ground was placed constantly in electric equilibrium with the atmosphere, and was, on the whole, permeated with a more abundant flow of static electricity than when in the normal state. The yield of cereals from the electrified fields was considerably greater than that of the fields adjoining.

When the electric fluid, instead of being diffused over the whole surface of the body, is applied to certain parts, and particularly the head, by the electric douche, for example, special phenomena may be seen to supervene that are consequent, probably, upon a modification of the hemispheres of the brain. But the most remarkable phenomena, such as the loss of memory, or, on the other hand, the return of memory when it has deteriorated—facts which have been noted by Benedict—fall under the category of therapeutic effects rather than of physiological manifestations.

We will point out later the excitation phenomena produced by an instantaneous flow—*i. e.*, by sparks.

Continuous Galvanization. Let us continue our examination of the facts regarding the continuous method of applying electricity. The second way is by the galvanic current, a method denoted ordinarily by the name of *continuous galvanization.* In this we apply rheophores to the skin, and by means of a suitable battery we send through the circuit, which includes the subject under electrization, a current which, starting at zero, should ultimately become of a certain intensity, and then gradually return to zero. The electrization is said to be continuous when everything is so arranged that the establishment of the current and its increase in intensity, and likewise the gradual return to zero, take place without shocks. In this way we suppress the mechanical effects of the galvanic current—*i. e.*, the electric waves or impulses resulting from the variations produced by making and breaking the circuit.

We do not mean to say, however, that the current even in this case is absolutely constant and invariable. For, when we apply a

20

galvanic current to any part of the body whatever, this current inevitably undergoes changes of intensity. The intensity, in fact, with the same number of elements, depends partly upon the resistance of the circuit, partly upon the condition of the battery. Now we shall see that, other things being equal, the resistance to the passage of the current varies at different times during the same electrization. On the other hand, however perfect the battery is, the current which it produces is always in a state of slight variation. The term constant current, therefore, is applied to a state in which there is an averaging of the effects produced by the slight and rapid oscillations of the variable state. And the characteristic mark of continuous galvanization from a physical point of view is the absence of sudden and great variations, such as those that result from the opening and closure of the circuit.

This method of electrization gives rise to phenomena that are peculiar to itself. It is logical for us to inquire about them in the first place, for in discontinuous or interrupted galvanization these phenomena are never absent, special effects due to the discontinuity of the application being superadded to them.

We shall begin by trying to find out how the galvanic current passes through the body or through one of its parts, and in what way it is distributed. It is evident that this question presents great practical interest. Hence it has given rise to quite a number of researches. Nevertheless, it is far from being solved.

The human body in its various parts, from skin to skin, or from mucous membrane to mucous membrane, or from skin to mucous membrane, offers a comparatively great resistance to the passage of a current. This resistance is due to the fact that there is interposed between the rheophore plates a mass of tissue which, in spite of the size of the section, is composed of parts that are comparatively bad conductors. When the rheophore plates are sufficiently far from each other, and particularly when one is applied to one surface of the body and the other plate is applied to the surface opposite, the resistance to the passage of a current is regarded as representing the total resistance of the human body. We shall see shortly that it is sensibly that of the two epidermic layers which the current has to traverse in order to pass from one electrode to the other.

The measurement of the resistance of the body is a question of pure physics, presenting special difficulties which do not seem to us to have been as yet overcome. Here we need only concern ourselves

with the results obtained and with the data which the practitioner can turn to account in the existing state of affairs.

The first observers made use of the substitution-method. To the results which Ritter obtained in animals have been added those collected in regard to man by Remak, Kohlrausch, Runge, Lenz, and others. When expressed in terms of Siemen's units of resistance they excite remark by their extreme diversity. Thus, while Runge, for instance, gives for the resistance of the human body the numbers 2000 to 5000 Siemen's units, Weber estimates this same resistance at 900,000 units.

Recently Gärtner, Rosenthal, Eulenburg, Jolly, Harris, and Laurence, have made use of the method of Wheatstone's bridge. In this way these observers have found that the resistance of the human body is much greater than one would have believed. The numbers which they give vary greatly, and we will content ourselves with mentioning those of the authors last named. Harris and Laurence used electrodes of 50 square centimetres held in the hand; they estimated the intensity with a mirror-galvanometer and determined the intensity in ohms. Their observations were made upon ten persons of various classes; and in some the hands were dry, in others wet. When the hands were wet—that is, under the conditions which ordinarily obtain in electrization—the resistance varied, other things being equal, from a maximum of 25,000 to a minimum of 3900 ohms. This discrepancy is considerable, and casts doubt upon the value of these experiments.

It is probable, however, that the resistance varies much from one individual to another, and also in the same individual according to the conditions under which one is placed. It was formerly supposed that the resistance reached its maximum at the points where the skin is the thickest—as on the palms of the hands and the soles of the feet. According to Gärtner, on the contrary, the maximum of resistance is observed in the region of the face and temples.

Be that as it may, the determination of the resistance of the body or of a part of it has no longer the same practical importance now that it had before the use of the intensity galvanometer. As the eye can be fixed upon this instrument during the whole course of the galvanization, we no longer need concern ourselves with the resistance that has to be overcome. Nevertheless we will add a few words in regard to the variations that take place in the resistance during the course of the galvanization.

Variations in the Resistance. One of the reasons for the discrepancies in the estimates of the observers who have endeavored to measure the resistance of the body depends upon the fact that the resistance, though very great at first—*i. e.*, at the beginning of the galvanization—rapidly diminishes. When galvanometers were used, the needle of which oscillated a certain time before reaching a position of equilibrium, the resistance measured was one which had already been modified by the physical and physiological actions which accompany the passage of a current. At present, by using other instruments, we measure the initial resistance and we find it very sensibly greater.

If we suppose that the resistance in the battery remains constant during the sitting—which cannot be rigorously true—the variations in the intensity of the current for the same number of cells will be in proportion to the variations in the resistance offered by the tissues. Now all experimenters have observed a more or less rapid diminution in the resistance, or, what comes to the same thing, an increase in the intensity after the passage of the current. This modification is produced more or less rapidly according to the region to which the current is applied and according to the intensity of the current used. In general it is more marked and more rapid in proportion as the intensity of the current increases. If we look at the needle of the galvanometer during the electrization, we see that the intensity of the current increases rapidly at first, and soon afterward more slowly until it reaches a certain maximum. According to Boudet de Paris, Stintzing, Groeber, and Dignat, if the duration of the sitting is prolonged after matters have reached this stage, the intensity sometimes tends to decrease once more, but never gets back to its initial point. Prolonged electrization, then, would at a certain moment create an increase in the resistance.

Gärtner, Silva, and Pescarolo have observed that interruptions of the current (closures or openings) have no influence upon the degree of resistance. But if we proceed to reverse the direction of a current, an increase in the intensity, which is often considerable, will be observed at once. Erb, Gärtner, de Watteville, etc., are all agreed upon this point, and it is important to remember it when we change the direction of the galvanization in the course of the same sitting. Lastly, we may note that von Ziemssen and some others have demonstrated a diminution in the resistance after a preliminary faradization has been done.

The reasons for these variations in the resistance are partly physical, partly physiological.

Besides moistening and soaking of the epidermis there are other modifications which we will describe presently, and which tend to diminish the resistance of the skin.

According to Gärtner, this physico-chemical action which is exerted upon the epidermis would suffice to explain the diminution in the resistance. He bases his opinion upon experiments made upon cadavers, experiments in which he removed the epidermis by means of hot water. But according to Erb and most of the other observers, we are likewise to take into consideration the cutaneous hyperæmia and the secondary excitation. After the application of revulsives or after the sudorific action of pilocarpine the resistance of the skin is diminished. As to the effect on the blood-flow, this has been studied by Dubois, of Berne. By cooling with a current of cold water the rheophore applied to the skin, this observer demonstrated an increase in the resistance produced by cutaneous anæmia. Some have invoked the polarization of the electrodes to explain the increase in the intensity of the current after reversal of the direction of the latter. De Watteville refutes this explanation, since he has determined an increase in the intensity, not immediately, but some moments after the reversal. According to Silva and Pescarolo, the diminution in resistance is produced mainly in the vicinity of the rheophore-plate connected with the positive pole. The increase, then, in the intensity of a current after its reversal may depend partly upon the lack of equality in the surfaces of the two electrodes. If the observation of these latter authors is accurate, the increase in intensity should be appreciable chiefly in the case when the small rheophore-plate was connected before reversal with the positive electrode.

The galvanic current penetrates into the depth of the tissues, and upon contact with the anatomical elements produces an abundant flow of electricity, giving rise to a comparatively large amount of chemical energy. It was necessary for us, first, then, to concern ourselves with the way in which the galvanic current penetrates and passes through the body. We have, therefore, learned that the body offers a very great resistance to the passage of the current, a resistance, however, which varies according to certain conditions, and markedly during the course of a single application of the galvanic current.

Conductivity of the Tissues. This resistance is a function of the

conductivity of the tissues which are to be traversed by the galvanic current. At present, then, we have to concern ourselves with the conductivity of the different tissues; and the facts which relate to this point will enable us to understand the principal laws regulating the method of distribution of the current to the interior of the animal economy.

It was recognized a long time ago that the skin possesses only a slight conductivity for the galvanic current. This depends mainly upon the resistance which the epidermis offers to the passage of this current. Hence the dry epidermis of a cadaver is destitute of conductivity. When moist the epidermis is a better conductor; yet, even in this state it represents the principal factor of the resistance. This is what Gärtner observed in the experiments previously cited. When the skin of a cadaver has been deprived of its epidermis the variations in the resistance of which we have spoken disappear almost absolutely. Jolly calculates that the resistance of the tissues interposed between the two epidermic layers may be ignored in comparison with that of the epidermis. The latter, then, constitutes a sort of protective varnish; it forms a kind of barrier. Once this barrier is passed, the galvanic current meets with layers that are much more conductive.

The attempt has been made to determine the conductivity of the different tissues, and for this purpose it was necessary to work chiefly upon the cadaver. The data thus acquired give us but imperfect information, for certain experiments tend to show that the conductivity of the living tissues is not the same as that of tissues that are dead. Thus, according to Ranke, living muscle would offer greater resistance than that of the cadaver, whilst other tissues, such as those of the nerves and nerve-centres, according to Munk and von Ziemssen, have less resistance in life than after death.

From a practical point of view we may admit with Erb that in the living subject the soft tissues all possess about the same conductivity. The bones, as Eckhard has shown, have the least conductivity. Danion represents by 1 the conductivity of the muscles, which may be regarded as the best conductors. According to him, the tendons are at least as good conductors as the muscles; then come the panniculus adiposus, the cerebral substance, and the aponeurosis, the conductivity of which is 0.93, while that of the bones is only 0.60.

Since the current is always able to twist its way about the bones

to follow the path furnished by the masses of muscle, it will in the interior of the body meet with masses having about an equal resistance in every direction.

This being granted, let us see how the galvanic current will behave after having passed the epidermis. This question should obviously be regarded as of the first importance. Unfortunately, as we shall see, it is far from being decided with any degree of precision.

Let us consider the case of some moist rheophore plates applied to the skin—one upon the front of the body, the other upon the back of it. We now know that they will be insulated with respect to each other by the epidermis. There will not then be even a trace of an external current tending to connect the two plates by passing round the surface of the body. It is consequently necessary for the galvanic current to be strong enough to overcome the resistance of the skin; or, in other words, of the two opposite layers of epidermis.

After having passed through the epidermis, the current behaves according to physical laws; it will then be distributed among the conducting tissues in inverse proportion to their resistance. Most specialists think that a kind of fan-like distribution takes place, the current starting from the surface of the rheophore and widening out in the depth of the body, then contracting again near the second plate. According to them, when there are given resistances to overcome a large part of the current will tend to connect the plates by the shortest way, provided, at least, that it does not in its passage meet a girdle of bone, which forces it to make more or less of a detour. This is the way in which Erb, von Ziemssen, and de Watteville have interpreted the behavior of the current in the interior of the body. Erb, to give a better notion of his idea of it, makes a picturesque comparison. He represents the current under the form of a head of hair, the number of hairs in which vary according to the density of the current. For a small rheophore surface a current of some intensity would be a head of hair composed of numerous hairs close together, so as to form a sort of tress or switch. Then, in the depth of the tissues, these hairs will spread apart, as if the whole mass of them had been set loose from one another and rumpled up; and then they will once more come together to form again a thick tress, which will pass on to join the other rheophore plate.

Derived Currents. The most scattered and eccentric hairs—*i. e.*, those which follow the longest path—form what are called

derived currents. A knowledge of the existence of a derivation of this sort is important in practice when we wish to avoid exciting very sensitive organs. It has been possible to demonstrate their presence experimentally; and this has, moreover, been put beyond doubt by various phenomena that occur in the course of certain kinds of electrization in man.

Thus the application of the rheophores in the vicinity of the eye, and even to the head, at some distance from the former organ, causes the development of phosphenes; electrization of the neck causes vertigo; and the application of the rheophore plates at a certain distance from the mouth (a distance which, when the current is intense, may be quite considerable) is accompanied by the development of a metallic taste.

Using this mode of distribution of currents as a principle, electricians have made rules for the application of the electrodes, varying according to the regions acted upon, and they have supposed that they are able to localize the effects of the electrization in certain organs by making such physical arrangements as shall be in accordance with the end in view.

They have, for example, enjoined that a small electrode should be placed at the affected point when this is a superficial organ, and that an electrode of large area should be placed at the point opposite.

Danion, who has recently taken up this question once more, has been led to regard as dubious the rules hitherto accepted. This electrician, from experiments made *in vitro* with regard to the method of distribution of the current in basins containing a saline solution, and which, according to him, represent the organic mass before it has been traversed by the current, arrives at the conclusion that we deceive ourselves when we believe that we reach a point, situated even a very slight depth below the surface of the body, with a current-density which is greater in proportion as the electrode nearest the point aimed at is smaller. His idea is that we should use large electrodes, which would enable us to utilize great intensities, which the pain excited by the small electrodes would render impracticable in their case.

You will understand how important it is to come to a decision with regard to the practical point raised by this discussion.

Danion aims to show that the current is diffused in the mass of tissue almost as in a mass of water containing a small amount of

salt (6 parts per 1000). Accepting this view, let us see what will be the conductivity of such a mechanism.

According to E. Becquerel, if the conductivity of silver is represented by 100,000,000, that of a half-saturated solution of sodium chloride is only 23.08; that of a weaker solution should be sensibly less, since the conductivity of a saline solution increases with the proportion of salt present in it.

If the human body were a mass of metal, the density of a current passing through it should be sensibly uniform at all points of it. In a mass which is three or four million times less conductive, the propagation of the electric flow will assuredly be much more influenced by the distance to be traversed; and it is with reason that all the classical authors have supposed that the flow tends to go by the shortest route. It seems evident to us, therefore, that in the interior of the body the electric density should he higher along the direct line of passage between the electrodes than at points remote from this line.

These considerations enable us to estimate approximately the influence which the surface of the rheophore plates exerts upon the density of the current in the deeper parts.

Every useful electrization should convey to the tissue or organ which it is intended to modify an electric flow of sufficient density to enable the electricity to exert an action of more or less amount. This rule should be regarded as fundamental. Accordingly, the injunction has been laid down to choose electrodes of such a character that, from the manner in which the electric flow is distributed, the current shall acquire its maximum density on the side where the diseased organ is situated. So when we wish to obtain great density, by applying an electrode of small area near the diseased point, we are forced to use a current which is much less intense than would be the case if the electrode had a more extended area. But, on the other hand, if we believe it useful to secure great intensity, it is indispensable that we have recourse to large electrodes, and we must inquire what density the flow will have under these conditions when it reaches the affected organs.

Let us suppose, in the first place, a very simple case, that of the electrization of a segment of the body by means of electrodes of the same area situated at two opposite points, and let us make use of the determinations made by Boudet de Paris. Supposc, moreover, that we use at first small electrodes of 5 centimetres on each side, or

having an area of 25 square centimetres. Under these conditions, the current intensity that could be used would, according to Boudet de Paris, be only 7.5 milliampères. The density of this current for each square centimetre would be 0.30 milliampère. If, now, we suppose that, in accordance with the mode of distribution admitted by most electricians, the diffusion of the current takes place in the tissues with a certain degree of obliquity, so that a centimetre distant from the plate the area of diffusion is 7.5 instead of 5 centimetres, the surface of section of the flow will at the distance of 1 centimetre be about 56 square centimetres, and the density will be about 0.13 milliampère.

Let us now replace this plate by a very large one of 22.5 centimetres on a side, or having an area of about 506 square centimetres. With the same angle of diffusion as before, the sectional area of the flow will, at a depth of 1 centimetre, be 625 square centimetres. But in this case we can use a current of 25 milliampère. In spite of this increase in intensity, the density of the current for 1 square centimetre will be only 0.05 milliampère, and this density at the depth of 1 centimetre will become 0.04 milliampère.

Let us put these figures down in tabular form :

At Surface of Body.

	Sectional area of flow.	Intensity in milliampères.	Density in milliampères.
Rheophore A,	25 sq. cent.	7.5	0.30
" B,	506 "	25.0	0.05

At Depth of One Centimetre.

Rheophore A,	56 sq. cent.	7.5	0.13
" B,	625 "	25.0	0.04

In both cases the density of the flow will diminish with the depth, but more rapidly in the first case (A), where the electrodes are smaller, than in the second (B). At a certain depth, in this instance 7 centimetres, the density of the flow will be equal in both cases, or 0.005 milliampère. But with the small plates it will then affect a surface of 500 square centimetres; with the large plates a much larger area, namely, 1600 square centimetres.

These calculations evidently can be only approximate, since we cannot determine with precision the degree of obliquity of the diffusion-cone, and since, moreover, the electric density is greater in the centre of this cone than in its periphery. But, such as they are,

these estimates seem, from the facts afforded by current observation, to be quite close to the truth, and we may, hence, draw from them important practical conclusions.

In the first place, we see clearly that large electrodes, while enabling us to make use of a current-intensity which is much greater than in the case of small ones, supply a flow of electricity of much less density, even on the surface of the body (in the proportion in the case cited of 0.30 to 0.05 milliampère. It is evident, then, that when we wish to act with a certain intensity of current upon a superficial, subcutaneous organ, there is every advantage in our using electrodes of small area, in spite of the necessity of using in this case a current of low intensity. The organ in question, if of small volume (nerve, ganglion, muscle, etc.), and if separated from the rheophore by only a minimum thickness of tissue, will receive, even with quite a weak current, a denser flow of electricity than from an electrization made with very large electrodes and with a much more intense current.

When, on the other hand, it is a question of acting upon a large, but still superficial organ (upon the stomach, for example), there will be certain advantages in using a pretty large electrode; not too large, however, since those of very large size afford only a diffuse flow of electricity of low density. These latter come in advantageously only when it is necessary to convey electricity either to an organ having a very extensive area or to a large group of organs situated at some depth from the surface.

We shall presently describe the effects of the excitation of nerves and muscles produced by discontinuous experiments made for this purpose; small electrodes are placed at the site of the organ that is to be stimulated, and a current of low intensity is employed. The results obtained would be incomprehensible if the current, after passing through the skin, were diffused equally in every direction.

When the rheophore plates are of equal area we speak of the electrization as *bipolar*. This method of application is often made use of in continuous galvanization.

As in the external circuit the flow of electricity takes place from the positive to the negative pole, special attention has been for a long time paid to the direction of the current, with the idea of determining the effects produced by this factor upon the part subjected to electrization. The name *centrifugal current* has been given to that which is obtained when the positive plate is, for example,

placed upon the root of a limb and the periphery of the latter. The opposite arrangement would give a *centripetal current.*

For some years past all that was formerly said regarding the influence of the direction of the current has been transferred to the polar action, *i. e.*, to a predominance of action at one of the poles.

We have just seen that when electrodes of unequal area, one very large the other comparatively small, are used, the current, if the intensity remains the same, will show a much greater density on the side where the rheophore of small area is situated than at the site of the other rheophore. The pole connected with the small electrode is called active, the other being considered as indifferent. Under these conditions the electrization is said to be unipolar or simply polar.

The differences observed between the effects of bipolar and of polar galvanization are chiefly pronounced at the times when the current is made or broken. They are likewise appreciable during the course of a continuous galvanization, under certain circumstances which we shall have to define.

The different considerations which we have discussed enable us to mark out the principal rules that should be followed in order to practise electrization in a useful and rational manner, while avoiding the disadvantages springing from an exaggerated density of the current.

When we wish to localize the action of the galvanic current in a superficial organ of small area and only slightly below the surface of the body, such as a superficial ganglion, a subcutaneous muscle, etc., we will use the polar method, which enables us to get rid of any effect upon the neighboring points, and to diminish, to a certain extent, owing to the large dimensions of the indifferent electrode, the total resistance of the body. The situation of what we call the inactive electrode is not always without importance. For continuous galvanization we should, in almost every case, select this situation in such a way that the current shall pass through the part to be affected with the greatest possible density. Thus, if we wish, for instance, to confine the action to a limited part of the spinal cord, we will apply the small electrode as near as possible to this part, and will make this electrode rather large, so as to be able to make use of a sufficiently strong current; then we will place the larger electrode upon the opposite side of the body over the abdomen, so that the current shall pass through the splanchnic nerves on its way to the spinal cord.

In all these cases the negative pole will be selected, according to the effect which we wish to obtain, our knowledge of the effect of polar actions being our guide.

To apply electrization to a large superficial organ, the better plan ordinarily will be to place an electrode of medium area at each end of it. When the diseased part is subcutaneous and quite extensive, as in the case of a joint, we shall do well to cover it completely with a suitable electrode.

Electrization of the nerve-centres has given rise to some difficulties. The low conductivity of bone has led to the belief, for some time prevalent, that it was not possible for a current to pass through the brain. Von Ziemssen, among others, shared this view up to 1866. In the following year Erb showed that currents having the intensity ordinarily used in therapeutic applications can pass through the brain and spinal cord.

Erb's researches were confirmed by Burckhart and Brückner, when Von Ziemssen, having taken up this question again himself, became convinced that the galvanic current can be made to pass through all the internal organs, including the nerve-centres. The medulla is particularly accessible to the current, because of the incompleteness of its osseous envelope, and because it is surrounded by muscular and fatty tissues.

Erb places one electrode upon each temporal fossa, and thus gets at the brain by using currents of weak intensity. Danion proposes to reach the brain by way of the orbit.

The spinal cord being protected by its envelope of bone and by masses of muscles, along which the current runs readily off, it is quite difficult to make a current of sufficient density run through it for its whole length. Erb places two large electrodes at the two ends of the vertebral column. It seems to us that under these conditions the current would have but little tendency to penetrate into the interior of the spine. According to von Ziemssen, the vertebral column must be covered almost completely by means of a long, narrow electrode, the second electrode being placed upon the sternum or in the hollow of the epigastrium. Danion, to get at the cord, uses a large bifurcated electrode, the two plates of which are applied to the post-trochanteric regions at the points of emergence of the sciatic nerves, the other electrode being placed upon the arch of the neck.

No one has insisted more than von Ziemssen upon the use of large electrodes. For electrization of the limbs he uses troughs, 40 to 50

centimetres long and 8 to 10 centimetres broad. Large articulations, like the elbow, knees, shoulders, etc., he surrounds with suitably shaped electrodes. These injunctions of his are perfectly proper when it is wished to convey the effects of a galvanic current to a large and superficial organ.

PHYSIOLOGICAL EFFECTS PRODUCED BY THE GALVANIC CURRENT. We are now going to describe the effects produced during the course of a continuous galvanization. Apparently they are very simple, for they consist only in the development at the rheophore plates of a more or less marked sensation, which at first is like a tickling, then a prickling, which increases with the intensity of the current. This intensity ought never to be great enough for the sensation to become painful.

It seems at first sight, therefore, as if this method of electrization were sensibly less active than the others. You are aware that the chief promoters of electro-therapeutics did not have recourse to it. Duchenne made use almost exclusively of induced currents. During the same period Remak popularized the use of the galvanic current, applied by what is called the *labile* method, which is only one variety of discontinuous galvanization. Continuous galvanization, properly so-called, is of a comparatively recent date. But it has rapidly won great favor, and for quite a long time back it has been regarded as capable of producing very marked effects.

The galvanic current is, as you should remember, in reality a current of quantity, generated by a comparatively large amount of chemical energy.

Let us, therefore, examine attentively the different effects that may result from it. We shall, in the first place, demonstrate the presence locally of certain marked physico-chemical phenomena.

After sending for a quarter of an hour a current of 20 milliampères through a portion of the body by means of electrodes of medium size, we see that at the site of the electrodes the surface of the skin has become red, as though treated with a mustard-plaster. By connecting the electrodes and joining them by conducting-wires to a galvanometer measuring electromotive force, we make a small battery, the electromotive force of which, according to Boudet de Paris, equals 0.6 volt. By connecting them under the same conditions with a galvanometer measuring current-strength, we get a deflection of the needle indicating 8 milliampères. Hence, during the course of the galvanization the electrodes have become charged;

they have undergone polarization, as the poles of a voltameter might have done, and have consequently been converted into the two elements of a small secondary cell.

This chemical and electrolytic action is not limited to the rheophore plate, but doubtless is continued into the skin, and we shall see later that when we place the electrodes in direct contact with the tissues, such as the blood, muscles, etc., there is produced at the site of the electrodes an energetic chemical action causing an alteration in the tissues. The general result of this chemical action is evinced in a transfer of the organic acids to the positive pole and of the bases to the negative pole.

This is the principal cause of the local, or cutaneous, effects. If, with a current of medium intensity, we prolong sufficiently the duration of the application, a more or less lively sensation of burning succeeds that of prickling; the skin becomes intensely red and covered more or less extensively with papules. If the application is suspended at this moment, the lesions remain superficial, and are followed at the end of some days by desquamation of the epidermis.

Moreover, a desquamation like that resulting from repeated therapeutic applications is usually produced even when the intensity of the current has never been raised to the point of exciting a sensation of burning.

Intense currents, particularly those which exceed the limit of the currents generally employed, give rise at once to phenomena that are more accentuated and more painful. At the negative pole, where a deposition of bases is produced, the vessels contract and the skin grows pale, and then takes on a rosy hue, while at the same time it rises so as to form a projecting patch, resembling that of urticaria. This elevation of the skin is due to a sort of œdema, which disappears quite rapidly, leaving in its stead a persistent redness. At the electrode which is connected with the positive pole, and at which the acids are deposited, the skin at once assumes a red color, which rapidly becomes intense and produces a dusky hue, and we observe here, instead of an œdematous infiltration, the production of small projections. The redness persists after the electrization, and is followed, after the lapse of some time, by an abundant desquamation of epidermis.

When the galvanization lasts a long time the chemical action produced upon the skin is so intense that disorganization of the derma and a more or less deep eschar result. It is very important to know

that mortification of the skin may take place as the result of any application that is sufficiently prolonged, and this, even when currents are used that are not very intense; and to know also that the production of this result is considerably facilitated by a bad condition of the electrodes.

It has been said that eschars are formed mainly at the negative pole or at the spot where the bases are set free. This proposition has been found to be inaccurate by Boudet de Paris. When the current is intense and has been applied sufficiently long, an eschar is formed, at each of the two poles. If only one eschar is formed its site is in the part in contact with the positive electrode. At this point the acids produce a coagulation of the albuminoid substances, and the eschar is hard and dry, while on the opposite side, at the point where the bases exert their action, the eschar is moist and soft, and requires for its production a more intense or a more prolonged action. The positive electrode, then, is, on the whole, the more dangerous of the two.

As the result of multiple and frequently renewed applications, made with currents of medium intensity, the skin becomes sensitive and irritable; it is covered with small papules, which become excoriated, thus rendering the application more painful. It then becomes necessary either to suspend the application or to shift the electrodes so as to apply them at the adjacent spot, which is quite intact.

The chemical action makes itself felt in the electrodes also, and wears them out. The best electrodes are covered with very supple chamois-skin. Under the influence of the chemical effect of which we have been speaking this skin becomes hard and dry, and then gets perforated. The surface of the patient's skin may then come into direct contact with the metallic surface. Our attention is usually called to this fact by the development of a violent pain; but if the cutaneous sensibility is blunted, the bad condition of the electrode may remain unnoticed and the formation of an eschar speedily results. The condition of the electrodes, therefore, should be looked upon with the greatest care.

Interpolar Electrolysis. The great majority of physicists and of electricians think that the galvanic current when it penetrates into the tissues produces there a chemical action proportional to its intensity. In other words, the mass of tissues is regarded as an electrolyte in which the current circulates, doing chemical work.

From a theoretical point of view the decomposition of the electrolyte represents the very cause for the conductivity of the tissues. It was, moreover, demonstrated a long time ago that every separate portion of tissue interposed in the circuit becomes polarized and causes the development of a force opposing the electromotive force. This last has been shown to exist by means of the same kinds of apparatus that serve to measure the electromotive force. We may refer in regard to this point to the experiments of Chaperon.

But under the conditions ordinarily present in electrization the chemical effects of the galvanic current can be recognized only upon the surface of the skin. Hence physicists, and among others Gariel, think that in the interior of the body there are produced a chemical decomposition and recomposition, from molecule to molecule, all along the circuit, in accordance with the well-known theory of Grothus.

Since the tissues may in a general sort of way be regarded as a sponge impregnated with the salts of sodium and potassium, the polarization of such an electrolyte would produce ultimately a disposition of the electro-positive bodies, like hydrogen, potassium, and sodium, at the negative pole, and of the electro-negative bodies, such as oxygen, chlorine, iodine, etc., at the positive pole.

A very simple experiment of Parsons seems to make this way of interpreting the chemical work in the interpolar circuit appear reasonable. Vessels containing a solution of potassium iodide are connected together by means of two pieces of wicking, passing respectively from the first to the second and from the second to the third. A strong galvanic current is then passed through the whole. The iodide is decomposed in the first and third vessels, but remains intact in the second.

Nevertheless, this theoretical view has not been accepted by all experimenters. A certain number of them will have it that the polarization of the tissues is the origin of more or less profound modifications in the latter. According to them, there are produced in the interior of the tissues phenomena analogous to those which develop at the points in direct contact with the electrodes, but the former phenomena are less intense than the latter, because the current which passes through the tissues has only a weak density and meets with a comparatively slight resistance in its passage. As a matter of fact, when the resistance in the portion of the course lying within the organism gets to be greater the chemical action becomes

appreciable. At least this is what an experiment made by Erb tends to prove. The two forearms are placed against each other, and the electrodes are applied to the opposite external surfaces of the two. After having sent a galvanic current through them for some time when they are thus placed, we shall find more or less rubefaction existing at the spot were the forearms were in contact—that is, the double layer of skin at this spot has set up a resistance to the passage of the current, and hence the electrolytic action of the latter has become manifest there.

As the current in the interior of the tissues necessarily meets with some resistances, some physicists compare the mass of tissues to an electrolyte divided off by partitions, and hence arranged in a favorable way for producing electrolytic decomposition.

E. H. Weber and Tripier have cited the effect produced upon taste as a proof of the electrolysis of the tissue. When the positive pole is applied to the tongue we get an acid flavor, while the application of the negative pole develops an alkaline taste.

Tripier places the positive and the negative electrode alternately upon one of the cheeks. The first gives rise to an acid, the second to an alkaline taste. The author draws the conclusion that the chemical disturbance produced is spread over an extended area. If now the circuit is closed by the application of both electrodes to the cheek, the taste perceived is neither acid nor alkaline, but simply metallic.

According to Rosenthal, in these experiments there is nothing but a simple excitation of the nerves of taste. He has called attention to the fact that the gustatory sensations persist sometimes for hours after the galvanization, and that consequently they cannot be referred to the chemical action due to the passage of the current.

Lastly, there is alleged as a chemical proof of the same thing the result obtained by Drechsel, who, by making alternating currents act upon a solution of ammonium carbonate, demonstrated the production of a certain amount of urea.

In order to decide this debated question, some direct proof of interpolar electrolysis has to be given. This has been supplied by an experiment which we owe to G. Weiss. This physicist electrified a frog's leg with a current of 1 to 2 milliampères for five minutes. As a result of the electrization the muscles of the thigh were found to be altered, and at the end of some days it could be demonstrated microscopically that they exhibited important lesions. If it is asked why, then, the muscles remain intact in man, the answer is that a current

of 1 milliampère for a frog's leg represents a current of more than an ampère for the thigh of a man, which is over a thousand times greater in bulk. It would be simply a question of the density of the current.

From these facts it is admitted that after galvanization the body when left to itself is found to be, as a result of polarization, charged like a secondary battery. To this idea Danion has raised the objection that it is impossible after an electrization to demonstrate by physical means the existence of a contra-electromotive force emanating from the parts that have been electrified; but it may be stated that if there is a polarization this phenomenon must of necessity be followed by a depolarization, and, if it is impossible to demonstrate the existence of the latter, this fact may depend upon the special conditions present when the polarization is accomplished. In fact, the process of depolarization must advance slowly on account of the relative degree of resistance offered by the intra-organic medium, and the electric flow to which it gives rise must be diffused over a considerable number of anatomical elements, and at the skin must meet with a resistance which prevents it from collecting outside. In other words, we must either admit that polarization and depolarization of the tissues both take place or deny the existence of both phenomena.

Certainly there are many points relating to this important question that have yet to be cleared up. But we may say—and physicists and electro-therapeutists are almost unanimous upon this point—that the chemical work of the galvanic current must be apparent somewhere, and that in the present case it is represented almost wholly by the polarization of the tissues.

CATAPHORESIS. The galvanic current produces also another interesting physical phenomenon known under the name of cataphoric action. Cataphoresis consists in the transportation or conveying of liquids and of minute particles which the latter hold in suspension. Observed for the first time by Porret, the transportation of liquids has been studied by Becquerel and by Wiedemann, who made known the laws governing it. This action of transportation, which is likewise manifested in the case of solid bodies, takes place sometimes, as Jürgensen has observed, in a direction opposite to that of the current. Sometimes, as Quincke has shown, in the same direction. The salts, which are subjected to electrolysis, are themselves objects of transportation.

G. Weiss demonstrates the transportation of solid bodies in the

following way: A U-shaped tube 15 centimetres long is filled with solidified gelatin and placed astride of two vessels containing a solution of eosin. A current of 0.10 miliampère is sent through the system, and in less than a week the branch of the tube connected with the negative pole is colored all the way through, while on the site of the positive pole the gelatin shows a colored part scarcely a centimetre long. If the experiment is repeated with methylene-blue instead of eosin, the positive branch is the one that becomes colored; *i.e.*, the transportation this time has taken place in the same direction as the current, although we know no reason for this difference in the two cases.

Owing to the small size of the anatomical elements, similar facts may occur in the interior of the tissues under the influence of the galvanic current.

In recent years the attempt has been made to utilize these phenomena of electrolysis and of cataphoresis with the idea of making certain medicines penetrate into the body. This matter will find its proper place in the part relating to the description of methods of electrization.

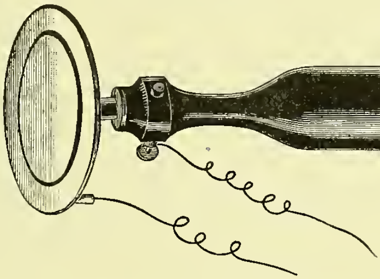
The reader has already been informed that a part of the energy of the current is expended in the production of heat. This production is almost *nil* in those parts of the circuit where the resistance can be ignored; it becomes appreciable at all points where the resistance is increased. Here the electrodes get warm where they are in contact with the skin; but under ordinary conditions, with the electrodes well moistened, the increase in temperature is only 1° to 1.4° C. for currents of 20 to 22 milliampères. We do not, therefore, have to take this class of effects into consideration.

Vesicant Effects. We shall see later on that the thermic effect of the current is used to produce galvano-cautery; but just at present it is only necessary to point out the effects of rubefaction and vesication, to which electrodes placed directly in contact with the skin give rise.

Boudet de Paris has devised a small instrument (Fig. 79), known under the name of the concentric stimulator and composed of a metal disk surrounded by a metallic ring of equal area. These two parts, which are separated by a slight groove, are mounted upon an ebonite plate, and are connected, one with the negative, the other with the positive pole. The stimulator being applied to the skin, it is only necessary to press upon the button in the handle to make the current

pass. Acute pain is at once produced; the skin reddens and then becomes vesicated as though by an application made with a Mayor's hammer. It is a very active revulsant agent, which, according to the inventor, is an application of the thermic action of the current. This interpretation has been doubted, and Bardet, among others, believes that there is an exaggeration of the chemical action analogous to that which is produced when the chamois-skin of an ordinary electrode is perforated and allows the metallic part to come into direct contact with the surface of the skin.

FIG. 79.



PHYSIOLOGICAL EFFECTS PROPERLY SO CALLED. Apart from these physico-chemical effects, is the galvanic current capable of setting into action the specific properties of the anatomical elements or of determining modifications in these properties?

We may, with absolute certainty, answer in the affirmative; but at the same time it must be noted that the question thus put is the most obscure of all that electro-physiology is concerned with, most experimenters having followed an anatomical or physiological order in studying organic reactions without taking sufficient thought of the physical conditions under which they placed themselves when investigating the various organs.

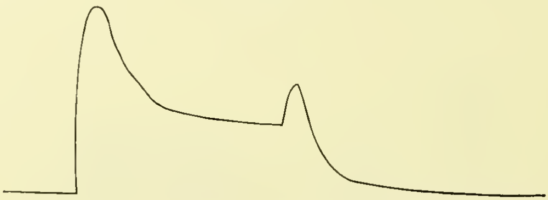
In particular there have been confounded in a one, common, description effects which are due to the action of the continuous current and those which are the result of the passage of waves which are more or less instantaneous.

We must try to separate these two orders of facts, and for the present confine ourselves to examining the phenomena that are attributable to the passage of the continuous current. Let us first take up the reactions of the muscles and the nerves.

Action Upon the Muscles. When a continuous current is sent

for an instant through the gastrocnemius of a frog we get (Fig. 80) a making (or closing) contraction followed by a less marked breaking (or opening) contraction. Between these two contractions the muscle-trace shows that the state of shortening of the muscle has persisted during the continuous stage of the current. This phenomenon is known by the name of galvanotonic shortening or contraction.

FIG. 80.



After the current is broken, the line of descent shows that the muscle regains its former length slowly, because of there being a sort of residual contraction.

Action Upon the Motor Nerve. If, instead of making the application directly upon the muscle, we act upon the nerve with a current-intensity sufficient to give us a reaction at both the time of making and breaking, we get a sensibly different trace (Fig. 81). During the continuous stage of the current the muscle returns almost absolutely to its original state.

FIG. 81.

How should we explain this difference? Should the persistent contraction of the muscle during the passage of the current in the first case be referred simply to a sort of residue of the primary contraction, which residue is absent in the second case? To solve this question, observers have applied electrization to a curarized frog, and by means of a rheostat have sent through the muscle a current which, starting from zero, increases very slowly and then diminishes in the same way. It is then observed that a galvanotonic contraction is

produced which increases little by little with the intensity of the current, and diminishes, too, in proportion as the current grows weaker. The contractions due to the variable state are thus suppressed.

The same experiment performed upon the nerve gives no muscular reaction at all.

We may from this draw the conclusion that a continuous flow of electricity without sudden variations does act upon the muscle, but is not adapted for exciting muscular contraction by stimulating the nerve.

Somewhat analogous effects may be observed when galvanization is performed upon man. When the galvanic current reaches a certain intensity the muscles tend to become tetanized, even though there are no abrupt variations in the intensity of the current. This result is observed only with quite strong currents which it would be difficult for the patient to bear; hence, they are not produced under ordinary conditions. The negative pole is more active in this respect than the positive. In any case, the tetanization due to galvanotonic contraction never has the wide extent or the energy of the tetanus produced by waves of electric action recurring in rapid succession.

Electrotonic Action. Although the galvanic current is not adapted for exciting an indirect contraction of a muscle—*i. e.*, a contraction produced by stimulation of the supplying nerve—it, none the less, exerts an important influence upon the physiological properties of the nerve through which it passes. The phenomenon in question, observed by Du Bois-Reymond, has been denoted in Germany by the name of *electrostatic action.* It has played a very important part in the various theories enunciated with respect to electric excitation.

Confining ourselves to a simple statement of facts, we shall understand by the term electrostatic action:

1. Manifestations indicating a modification of the specific excitability of the nerve.

2. Electric manifestations.

We owe to Pflüger a study of these manifestations, which has become a classic; we will, however, content ourselves with enunciating the principal facts discovered by this physiologist, and verified a great many times since.

The passage of the galvanic current through a nerve results in a change in the way in which the nerve responds to the action of

stimuli. This modification is produced directly upon the passage of the current. It makes itself felt through the whole extent of the nerve, but chiefly in the vicinity of the poles.

At the negative pole and in its vicinity, both above and below, the excitability of the nerve is increased. This phenomenon is known under the name catelectrotonus (from the word cathode, which is used to denote the negative pole).

On the other hand, at the positive pole and its vicinity, both above and below, the excitability of the nerve is diminished, a phenomenon which constitutes what is called anelectrotonus (from anode —positive pole).

Between the two poles there is an indifferent zone, in which the physiological properties do not undergo any modification.

The effects produced by the passage of the current are proportional to the duration and intensity of the latter, and they persist for a certain time after its cessation. However, all observers are not agreed upon this latter point; according to some, the phenomena produced are instantaneous, and appear and disappear with the current.

It has also been noted that while these manifestations last there is a modification produced in the ability of the nerve to conduct stimuli coming from another point of the nerve. The results, however, obtained by different observers have been contradictory upon this point. Hermann, who has taken up the study of this question, has found that, synchronously with the modifications in the physiological properties of the nerves produced during the passage of the current, the electrified nerve is the seat of electric manifestations attributable to polarization.

The French electricians, d'Arsonval and Boudet de Paris, refer what are called electrotonic phenomena likewise to polarization of the tissues. However, this question, although already so much discussed, cannot be regarded as definitely settled.

The nerves are not the only organs whose physiological properties are affected by the passage of the galvanic current; phenomena analogous to those which we have just described are likewise displayed in the muscles, but the passage of the current must last a much longer time in order for these phenomena to become appreciable.

The sensory nerves of the skin show after electrization an increase in this excitability. If after galvanization of some minutes, made with a current of some intensity, the direction of the current is

reversed gradually and without the production of any shocks, the patient experiences acute pain, and can scarcely bear a current a fourth or a third weaker than the first. It is only at the end of several minutes that we are able to get up to the same current-intensity again. We may conclude from this that the polarization produced in one direction renders the cutaneous nerves more excitable the moment the direction is changed.

We will class with these observations those relating to what is called the fatigue-action exerted by the continuous current.

When, as a result of repeated excitations, the muscle of an animal contracts but feebly—when, in a word, the muscle is fatigued, we may, as Heidenheim has shown, restore the original excitability of the organ by sending a galvanic current through it for several minutes.

To remove fatigue, or restore a muscle, it is necessary to use a current opposite in direction to the first, *i. e.*, it is necessary to depolarize the muscle. De Lyon has shown that this effect is observed in the muscle of a living man. Poore likewise has observed that the muscles of man, when exhausted by continuous exercise, can have their vigor restored by means of galvanization.

The continuous current exerts a large number of stimulating effects in addition to those described. These, however, are not so clearly marked in their development as the latter, inasmuch as they have been observed under conditions that are more or less complex.

The current appears to exert a special action upon the unstriated muscles, doing so either directly or perhaps rather through the medium of the sympathetic motor nerves. This property has been put under contribution by therapeutics.

The galvanic current is furthermore a stimulant of all the nerves of the great sympathetic, and particularly of the vasomotor nerves. The modifications in the circulation produced by it were observed by Remak, who used what are called labile currents. Since then they have been likewise observed as a result of the application of the continuous current. They explain in part the trophic effects produced by this method of electrization.

The special senses are likewise very sensitive to the action of the galvanic current, but in this case it is impossible to separate the effects due to the passage of the current from those which are set up by the abrupt variations produced by its continuous action.

The same remark may be made regarding the phenomena observed with respect to the secretions. Nevertheless, it seems well estab-

lished that continued currents are able to render most of the secretions more active.

The cerebrum is markedly affected by the passage of the continuous current. But there again the facts that have been observed in man are difficult to interpret on account of their complexity. In fact, when we apply electricity to the brain we at the same time stimulate the sensory nerves (of sight, taste, and more rarely of hearing) and various vasomotor nerves, the setting into action of which may disturb the cerebral circulation.

The characteristic phenomena produced upon the brain by the repetition of the current consist in the development of vertigo, accompanied by a sensation of cerebral malaise and disturbances of consciousness, and sometimes also by a sensation of external objects being displaced. When the currents used are sufficiently intense, there are produced, as Hitzig has shown, associated movements of the eyes, oscillations of the body, and attacks of vertigo. There have been also noted under these conditions vomiting, pallor of the face, somnolence, and syncope. According to other observers, the continued current is also capable of producing symptoms of cerebral congestion, eclamptic convulsions, and even hemorrhage into the brain. Feinberg has observed modifications of the temperature, dependent, no doubt, upon vasomotor disturbances.

Usually the supervention of vertigo is avoided when the electrization is performed parallel to the sagittal suture, *i. e.*, from one temple to the other. Oscillations of the body become apparent only when interruptions are made in the current. We may also mention the fact, of which Duchenne has noted an instance, that blindness may possibly occur after an application to the head.

The spinal cord appears likewise to be subject to impressions produced by the passage of the electric current. But here again the conditions of observation are very complex, for it is difficult to single out the phenomena due to excitation of the vessels and nerve-roots and to distinguish them from those referable to excitation of the substance proper of the cord, which many physiologists regard as incapable of responding to an electric stimulus.

However it may be in regard to the obscurity from a physiological standpoint of the facts that we have been citing, it is none the less certain that electrization of the nerve-centres (brain and cord) produces therapeutic effects in disease.

From this collection of facts it would seem as if the continued

current ought to exert a notable effect upon the general nutrition. And yet the researches followed out by d'Arsonval with regard to the influence of various methods of electrization upon the processes of respiratory combustion have turned out negative as far as the continued current is concerned.

In the experiments of this author made both upon man and upon animals the products of respiration were analyzed either immediately after electrization or twenty-four or forty-eight hours later.

It would be interesting to take up the investigation again and to verify the results announced by d'Arsonval, making in addition researches upon the modifications which may be produced in the urine.

The principal facts with regard to the action of the current may in the present state of our knowledge be summarized as follows:

The galvanic current penetrates into the depth of the tissues and is diffused through an area the extent of which depends upon the intensity of the current and the physical conditions under which it exerts its action.

Through the whole of its course the phenomena produced are dependent upon the density of flow when the current reaches the several organs, and is proportioned to the specific excitability of the latter. But while there is this tendency for certain specific phenomena to be brought into play, there is at the same time a general effect produced in common upon all the tissues through electrolytic molecular polarization.

This physico-chemical work stirs up, so to speak, all the organic molecules, and, owing to depolarization, is followed by molecular work of another kind.

These are the effects of a chemical nature which constitute probably the principal and specific action of continuous electrization. If those who doubt their existence were correct, the therapeutic indications of this method of electrization would be considerably reduced.

It is likewise admitted by most physicists, and practitioners agree in recognizing the same fact, that when a material lesion is in question preference should be given to the galvanic current.

One of the probable consequences of this physico-chemical action consists in those modifications of the properties of the nerves, and to a less extent of the muscles, which correspond to the phenomena known under the name of electrostatic action.

The galvanic current is a stimulant of the sensory nervous system, and may in this way give rise to reflex action. It is a stimulant of

the great sympathetic nervous system, and doubtless also of smooth muscular fibre and of glandular organs.

By these various means it may set up vascular and secretory modifications, which take a large share in producing the trophic effects which are admitted to spring from it.

Furthermore, the indication is for us to have recourse to it in cases in which we wish to act upon the living organs called vegetative.

Finally, the galvanic current either directly or indirectly modifies the central nervous system (brain and cord), and exerts upon these organs effects of stimulation, or, on the contrary, of depression, according to the pathological circumstances present, and also according to the way in which it is applied.

In a word, it cannot be contested that in it we possess one of the most powerful of therapeutic agents.

Variation Method. Having made a physiological study of the continued method of applying electricity, we are now to take up the effects produced upon the organism by temporary currents or electric waves. We shall have to distinguish between single waves and those that recur periodically.

The questions regarding the physical conditions produced by means of these methods of excitation, and the physiological data relating to the same subject, are still at present the object of theoretical discussions. It will be necessary for us in the main to take cognizance of well-established facts, without concerning ourselves for the time being with the explanations of them which may be adduced.

In order to produce stimulation by means of electric waves we use in practice discontinuous electrization, discharges from a tinfoil condenser, induction currents, and the static discharge. We will complete our statement by summing up briefly the data recently obtained with respect to the effects produced by sinusoidal alternating currents.

The discontinuous or interrupted current produces the effect of the continuous current, and, in addition, those which the variable state exerts upon the nerves and muscles.

Working, as we ordinarily do, with medical batteries or the kinds of induction-apparatus employed in practice, we find the physical conditions complex and perhaps as yet not sufficiently defined. And yet it is under these conditions that we most often use electric waves, not only in order to obtain a therapeutic effect, but also to investigate the state of the nerves and muscles from a diagnostic point of

view. We keep in mind, however, as the main thing, that with the continuous current in particular the action produced is the result both of effects due to the permanent state and of those due to the variations.

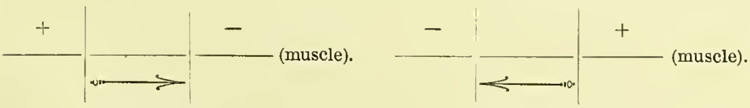
In practice the time during which the current passes through the organs is always much greater than the time taken up by the variations of making and breaking. Now we have just seen that the passage of the current, or the continuous state, produces modifications in the physiological properties of the muscles and nerves proportioned to the intensity of the current, the duration of its application, and the depth at which the organ affected is situated. We must hence expect to obtain quite variable results by very reason of this variability in the conditions of observation. As most electricians at present admit that the continuous current entails a polarization of the tissues, we may say, in a general sort of way, that the effects of the variations of which we are going to speak, are complicated by the modifications produced by polarization of the tissues.

In reality we find ourselves at present confronted by empirical observations the interpretation of which is still very obscure, and which, nevertheless, it is our business to be acquainted with, because of the practical services which they daily afford.

Let us, in the first place, start with the facts regarding the excitation of the motor nerves.

Physiologists who have studied this question upon mutilated animals have used sometimes the polar, sometimes the bipolar method. Although at present we make use in practice only of the polar method, it is proper to call attention to the results which Pflüger obtained by using the bipolar method. These results are known under the name of the law of contractions. We may represent them under the following form :[1]

Descending current. *Ascending current.*



	Descending current	Ascending current
I. Weak current	Cl	C Cl.
	Oo	O o.
II. Medium current	C Cl	C Cl.
	O Cl	O Cl.
III. Strong current	C Cl or C Te	C o.
	Co	O Cl.

[1] Here and elsewhere in the book C denotes closure ; O, opening ; cl, a weak clonic contraction ; Cl, Cl″, Cl″, etc., clearly marked clonic contractions of successively increasing intensity ; and Te, Tonus. We thus see that with the weak current we get, if it is descending, a slight contraction, and, if it is ascending, a well-marked contraction upon closure of the circuit.

We see that the results obtained vary with the intensity of the current and with its direction. Most of them are easy to understand if we take into consideration the difference between the character of the variation of the current at the moments of opening and closure, and also take into account the following propositions:

The excitation is greater at the point at which the current leaves the body than at the point by which it enters it. This law appears to be the corollary of what is called electrotonic action.

The reader will call to mind the fact that at the moment of closing the circuit the establishment of the current is supplemented by the addition of a certain intensity, due to the fall of potential (difference between potential of the open and the closed circuit), while at the moment of breaking we have simply the cessation of the current.

Nevertheless when we endeavor by means of these data to interpret the experimental facts recorded in the table, some of the results are such that there is room for various theoretical explanations.

The laws of unipolar excitation have been studied by Chauveau by means of experiments which go back to 1859. About this time Baierlacher was also busy with this same question.

A little later the unipolar method was applied to the diagnosis and treatment of diseases of the neuro-muscular system by Brenner, whose studies were completed by Filehne, Erb, de Watteville, etc.

Chauveau placed animals or man in a bath, the better to insulate the active pole, and arranged the results which he got under the form of curves. He has thus established for the excitations produced by closure of the circuit that there is a certain current-strength (in general, a moderate one) with which we get contractions equal in size and duration at both poles. With greater current-intensities the negative pole is the more active, with less intensities the positive pole is the more active. When the intensity of the current is increased the action of the positive pole increases with it, often in a regular manner, being then represented in the graphic construction by an oblique straight line more or less ascending, while in other cases it is represented by a line more or less curved. The action of the negative pole at first increases with the intensity of the current, then the increase takes place more slowly or the action becomes stationary, and sometimes even shows a slight decrease.

We thus get

$$CaC > AnC;$$
then $CaC = AnC$;
then $CaC < AnC$.[1]

Excitations due to the breaking of the current give the contrary results. The negative pole has but a slight tendency to excite contractions at the moment of opening the circuit; hence, with a moderately strong current, we simply observe an AnOCl, later on the action of the two poles becomes equal, and then the action of the negative pole increases in proportion as that of the positive pole grows weaker. We hence have:

$$CaO < AnO;$$
then $CaO = AnO$;
then $CaO > AnO$.

The observations of Chauveau have been confirmed by various authors, and have been completed in certain points by Bondet de Paris.

In Germany, in order to obtain unipolar excitation in man, they apply a large or inactive electrode, as it is called, to a spot that is not very sensitive, such as the sternum, tibia, or vertebral column. We may also immerse the lower limbs up to the mid-leg in a tub of warm water. To get results that shall be comparable with one another it is necessary to secure all of them under the same conditions.

What is called the active electrode is represented by a pad placed in the immediate vicinity of the nerve, *e. g.*, just above the epitrochlea when it is designed to stimulate the ulnar nerve at the elbows.

Helmholtz states that this arrangement brings about physical conditions analogous to those of bipolar excitation.

By looking at the schematic drawing (Fig. 82) we see that there are formed over the course traversed by the current poles which Erb has denoted by the name of virtual poles.

In the present case, for one positive pole we have two virtual negative poles, *i. e.*, two segments at which the current comes out the nerve with a certain density.

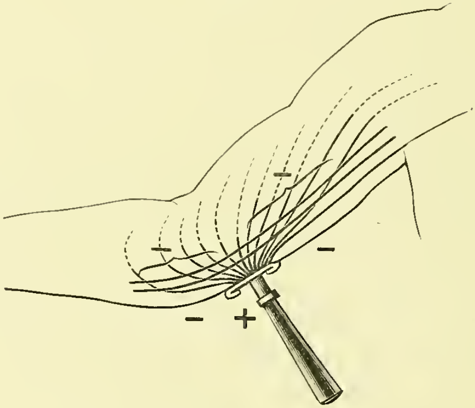
The predominant action of a pole which is applied close to a nerve is determined by the density.

[1] AnC, AnO, mean the reaction taking place at the positive pole (anode) at the closing and opening of the circuit; CaC, CaO, the reactions at the negative pole. AnCCl, AnOCl, CaCCl, CaOCl, might be substituted for these expressions, as has been done in the tables later on, where also it is regarded as worth while to indicate the greater or less intensity of the reaction.

The results obtained in man by Brenner under conditions of this nature have been verified by Erb. They may be summarized as follows:

In the first place, we notice that the negative pole gives shocks mainly at the closure of the circuit, the positive pole mainly at the opening of the latter. This general law agrees with Pflüger's law of shocks, when we take into consideration what are called virtual poles, and also agrees with Chauveau's law.

FIG. 82



The action of the negative pole is much more marked than that of the positive pole. When we use this pole the shocks are abrupt and instantaneous until we get to the point where tetanic contractions are produced.

The first effect obtained, then, is CaclO, and to get other effects we must increase the intensity of the current. Erb gives the three following successive degrees of action according to the strength of the current:

Degree of Current.	Effect Produced.
1. Weak current . .	CacO.
2. Medium current . .	CaCCl′; AnCCl, AnOCl.
3. Strong current . .	CaCTe, AnCCl′, AnOCl″, CaOCl.

The variations from this scheme that may be observed in man are referable to the greater or less depth of the nerve below the surface.

By increasing still more the intensity of the current we should see AnOTe develop. This result cannot be obtained in the healthy man.

For the same nerve, and the physical conditions of the examination remaining always as nearly identical as possible, the results obtained are constant. They can, therefore, serve as a guide to the diagnosis.

In the tables which Erb has drawn up the intensity of the currents used is not noted in milliampères. The following table is one in which are summarized several examinations made upon the ulnar nerve of man by means of a current of increasing intensity, measured in milliampères:

Intensity in Milliampères.	Negative Pole.	Positive Pole.	Positive Pole after Polarization.
I. 4 to 5	CaCcl or CaCcl′		
6	CaCCl	AnCcl	AnOcl.
II. 9 to 10	CaCCl′	AnCcl′	AnOcl′.
12 to 13	CaCCl″	AnCcl′, AnOcl	AnOcl′.
III. 14 to 15	CaClTe, CaOcl	AnCcl′, AnOcl′	AnOCl, AnCCl.
18 to 20	CaClTe, CaOcl′	AnCCl, AnOCl	AnOCl′, AnCCl.

Above 20 milliampères (an intensity which it is difficult to get the patient to stand), an OCl > CCl up to 25 milliampères.

Erb has justly observed that the examination of a nerve made for purposes of diagnosis should be performed according to a fixed, invariable method. He proceeds in the following manner:

He begins at the negative pole with a current of low intensity and determines three times in succession the value of the current, which gives CaCCl. Then he increases the intensity of the current until he succeeds in producing AnOCl. This done, he changes the pole and tests for AnCCl and AnOCl. When he wishes to get the breaking contraction at the positive pole, he is careful to let the current go on for some time so as to increase the excitability of the nerve. The intensity of the current should be progressively increased until a tetanic contraction is produced. Normally, the single contraction Cl (which is denoted by cl when it is very slight) is followed by successively stronger contractions, which may be denoted by Cl′Cl″Cl‴.

The conditions of examination are fortunately favorable when it is possible to make upon the same subject a comparative test of both the sound and affected sides.

The author uses a sensibly different method. He begins in the same way—*i. e.*, by placing the negative pole upon the nerve, since this pole always gives the first reaction—and, after having repeated two or three times with a low current-intensity the making and break-

ing excitations, and noting the results of examination, he reverses the current and, using the same current-intensity, tests the positive pole.

It is only after making these successive tests of the two poles with the same current-intensity, and for both the closing and the breaking of the circuit, that the intensity of the current is increased; then he once more begins manipulating with the negative pole, afterward takes the positive pole, and so proceeds.

This reversal of the current seems to me to do away with the effects of polarization more effectively than does Erb's method.

The results recorded in the last column of the table are those which we get when the circuit is broken after electrization of the nerve has been carried on for some time.

Muscles are endowed with contractility, and this property is peculiar to them. But in the normal state we cannot act upon muscles without at the same time acting upon their nerves.

The stimulant action of the electricity, therefore, is exerted upon a complex tissue, and the effect which results from it is, in some measure, a resultant and not a simple action. Hence, in certain pathological cases in which the nerves are altered we observe modifications in the muscular reactions.

Most physiologists, among whom I will mention von Bezold, Hering, Engelmann, and Biedermann, think that for excitations of the muscles there is a law analogous to that which governs the excitations of the nerves. According to Wundt, this law holds good only when the electric stimulation is applied to the upper part of the muscle. It is no longer exact when the whole length of the muscle is contained in the circuit.

The facts observed in man or in an animal that has not been vivisected are distinct according as the excitation is bipolar or unipolar.

When we perform bipolar excitation, by means of electrodes placed outside of the points where the motor nerves make their entrance, we get a contraction limited to the parts comprised between the two poles and the parts in their vicinity. The making variation is the only one that is active; the contraction at the breaking of the circuit is either absent or occurs as a rare exception. The muscular contractions are less abrupt than those which result from stimulation of the nerve.

In the case of unipolar excitation, the reaction CaCCl is not much more intense than AnCCl, a result which, according to Hering, is

the consequence of the anatomical conditions presented by the muscle. For in this case, especially when the application is made to large masses of muscle, he holds that multiple virtual poles are formed, which prevent what is called the active pole from having any marked superiority of action.

It is important to remember that the muscle remains tetanized during the passage of the current, and that this peculiar state may render the effect of breaking the circuit less appreciable; yet if we work upon an animal and take tracings of the contraction, it is easy to demonstrate, by beginning with the production of a breaking variation, that the effect due to closing of the circuit is the preponderant one.

Following various physiologists, Wundt and Boudet de Paris, who made a comparative study of the effects of direct and of indirect stimulation of a muscle, have shown that when of equal intensity galvanic excitations do not act in the same manner upon a nerve and upon a muscle. A stimulus that is incapable of producing tetanus, when acting through the medium of a nerve, can, when applied to a muscle, produce tetanic (electrotonic) contraction. The two poles show themselves equally active in this regard.

We shall have to return later on to the probable causes of these differences between the muscular and the nervous reactions.

Unipolar stimulation of healthy muscles in man has given results which may be presented in tabular form as follows:

Intensity in Milliampères.	Negative Pole.	Positive Pole.
5 to 6	CaCCl	AnCcl.
8 to 10	CaCCl′	AnCcl′.
12 to 15	CaCCl′	AnCl, ANOcl.

Physiologists generally agree with Pflüger in the belief that the reaction of the sensory nerves obeys the same laws as those which regulate the motor nerves. In regard to this matter we may point out only the results obtained in man.

The first reaction observed is that which the negative pole produces at the moment when the current is established. We hence have to start with CaCS[1], when the sensation represented by the symbol S is brief and resembles a prickling. When the current becomes stronger this sensation is more accentuated and more persistent, but is local and eccentric. It disappears gradually during the passage of the current.

[1] S for sensation.

The intensity of the current must be increased still more to produce AnOS, which gives rise to a rapid sensation, and then AnCS, manifested by a sensation which, though slight, persists during the passage of the current.

If, with intense currents, after having obtained CaCS, we wait until the sensation produced by breaking the circuit has disappeared, CaOS gives a weak but still distinct sensation. During the whole duration of the test the patient experiences a sense of burning at the point where the electrode is applied.

It is seen that for sensory, as well as for motor nerves, the negative pole mainly produces reactions at the time of closing the circuit; that, on the other hand, the positive pole gives rise to reactions when the circuit is broken; and that in this case also the negative pole is still the more active of the two.

The nerves of special sensibility are very readily affected by the current. We possess results upon this point, many of which have been obtained by various physiologists upon themselves.

The eyes are particularly sensitive, a fact which explains the development of luminous sensations and of the flashes of light that occur, as we have seen, under the influence of induced currents produced in the course of electrization of the neck or even of the chest.

The first observers—Volta, Ritter, and Helmholtz—have described the effects of galvanic currents, without taking account of the polar action and without distinguishing the effects of the continuous state from those which are referable to the variable state.

We owe to Brenner (1862) the statement of the laws governing the phenomena produced by polar stimulation. This observer found that each interruption of the current (O or C) excites an abrupt, luminous sensation, accompanied by the production of a rapid, lightning-like flash, but with a hue varying according to the pole employed. Thus:

	Flash.
With CaC	reddish or pale yellow.
" CaC	bluish or blue.
" AnC	bluish or blue.
" AnC	reddish or pale yellow.

The use of intense currents generate in the field of vision a brilliant figure, taking the shape of a parallelogram or a polygon, surrounded by a pale aureola, likewise varying in color according to the pole that is acting and the nature of the variation (O or C). But the

color-effects vary according to the subject; the flash always showing the same hue in the same person, but varying from one person to another.

These luminous phenomena result from the stimulation of the retina or optic nerve, it not being possible to localize their point of origin more precisely than by this general statement. To obtain them the inactive electrode is applied to the nape of the neck or to the sternum, the active electrode being upon the closed eyelid or upon the temple. The subject should be placed in a dark room.

It is likewise Brenner's observations that have made us acquainted with the law of stimulation of the auditory nerve. This nerve appears to behave like a motor nerve. For here, again, the negative pole shows its superiority of action over the positive pole and produces effects mainly at the making of the circuit, while the positive pole acts mainly at the moment when the circuit is broken.

Currents of medium intensity give CaCAu,[1] when they are stronger we get 1CaCAu′ (when Au′ represents a more intense sensation). To obtain AnOAu, Erb advises that before breaking the circuit the current be allowed to flow for some time, so as to polarize the nerve.

The quality of sound perceived varies according to the subject, most generally in the healthy state; the sensation produced is compared by the persons subjected to the test to a whistling, a buzzing, or a bubbling, when the currents are of moderate intensity; strong currents cause, under the same conditions, a more intense, more musical sound.

Formerly, in order to make an electrical test of the hearing, a special electrode was introduced into the external auditory canal. This troublesome method has been given up ever since Erb showed that the results obtained are sensibly the same when a small pad-electrode is applied somewhat forcibly to the tragus, the other electrode being held against the nape of the neck.

We have already had occasion to speak of the great excitability of the nerves of taste, so we shall not need to return to this subject at present.

The reactions of the olfactory nerve, which have been but little known, have been studied recently by Aronsohn under the direction of E. Remak. To obtain them this observer fills the nasal cavities with a weak saline solution at a temperature of 38° C., and introduces into the nose an olive-shaped electrode, while a large electrode is placed against the forehead. The effects produced are analogous

[1] Au—auditory sensation (sound).

to those which Brenner has noted with respect to the auditory nerve. The subjects experienced with CaC and AnO specific sensations, which did not, however, recall, as some have said, an odor of phosphorus. Very weak currents of 0.1 to 0.2 milliampère suffice to produce these sensations.

The effects caused by excitation of the secretory nerves have been little studied in man. Nevertheless, it is certain that electrization, and especially discontinuous application, can increase either by direct or by reflex action the activity of the various secretions. It is, for instance, possible to excite an abundant secretion of saliva by means of continuous or discontinuous electrization of the parotid region. The author has been able by this means to bring back the buccal secretion in an old woman convalescing from a gastro-intestinal affection from which she had derived a marked dryness of the tongue and mouth.

From experiments that have been made upon animals, the effects of electrization of the parotid region may be referred in part to stimulation of the chorda tympani. In man there is perhaps reason for invoking as the chief means of accounting for them a reflex action taking place through the medium of the gustatory nerves, whose excitability is quite great.

A great number of experiments made upon animals have shown that electrization of the great cervical sympathetic produces important vasomotor effects. But in almost the whole of these experiments the induced current has been made use of. No inference, therefore, can be drawn from them with regard to the phenomena which can be produced in man by electrization of the sympathetic in the neck, a method with which physicians have been actively working for some years back. Moreover, it is impossible in this method of electrization to limit the action of the current to stimulation of the sympathetic alone; we at the same time stimulate the vagus and brachial plexus, and certainly, too, excite various reflex actions.

In experiments made by G. Fischer upon horses and cats, electrization of the sympathetic in the neck, performed through the skin, as in man, produced modifications of the cerebral circulation. These effects can be referred as well to centripetal stimulation of the vagus and of the cutaneous sensory nerves as to stimulation of the cervical sympathetic.

In man the phenomena observed are very complex. There have been obtained various pupillary reactions and disturbances of circu-

lation in the fundus of the eye, disturbances which are manifested sometimes by hyperæmia, sometimes by anæmia. Beard, Bulenburg, and Schmidt have noticed a lowering of the arterial pressure, a diminution in the number of pulsations, and hence corresponding modifications in the sphygmographic trace. These effects are probably the result of stimulation of the vagus. The same method of electrization may also, according to A. Meyer, determine an elevation of temperature, showing itself usually in the corresponding arm, and an excitation of the secretion of sweat, visible at the tips of the fingers and in the palm of the hand. Adamkiewicz has, it will be recollected, obtained analogous sudorific effects by stimulating the cerebro-spinal nerves.

We may also note among the results of the electrization of the neck somnolence, vertigo, and various disturbances of the peripheral or central circulation.

It has been asked if the heart is affected by the passage of the current or by variations in the latter. The question has been studied in man by Von Ziemssen in a case in which, owing to a resection of the ribs, the heart beat directly beneath the skin.

The current-variation due to making the circuit (CaC), the continuous current (the negative pole being placed upon the heart), and successive reversals of the galvanic current, result in an increase in the number of heart-beats. Intense currents and slow excitations produce a slowing of the heart's action. According to Von Ziemssen, the cardiac muscle may, as regards its selective reactions, be placed in a similar category with other striated muscles.

Stimulation of the phrenic nerve produces contractions of the diaphragm, which are not painful and which obey the law governing the motor nerves.

The stomach, intestines, urethra, bladder, and uterus—in a word, all hollow organs containing smooth muscular fibres, appear to be very sensitive to the action of the galvanic current; but so far we lack precise and decisive experiments upon this point.

From observations made upon man by Boudet de Paris, the most distinctly marked intestinal reactions occur when we reverse the current, and when we interrupt it after having produced polarization by means of the continuous current kept up for some time. The same perhaps is true for all the other organs containing smooth muscular fibres.

It is to Chauveau that we are indebted for the first studies of the polar stimulation of nerves by means of induced currents. This ob-

server was the first to make the important observation that induced currents being of high electromotive force, whose polarizing effect can be ignored under ordinary conditions, afford more regular results, particularly when we make our applications to animals whose spinal cord or whose nerves are divided.

The facts observed in man are simpler than with the galvanic current. In fact, we have only to consider two varieties, that of closure being too weak to produce an appreciable stimulation; the variation produced by the breaking of the current is, for the physical reasons, the only one that is active; and the stimulation of nerves, by means of the induced current, accordingly, is less interesting from the point of view both of diagnosis and treatment.

With weak currents the reaction produced at the negative pole is the only one that is followed by an energetic contraction, no reaction being obtained with the positive pole. The result remains the same, whatever be the direction of the current; *i. e.*, whatever be the plane of the inactive pole.

When the currents are stronger both poles are active, but the reaction produced when the negative pole is used is always more intense.

Stimulation of a nerve by induced currents hence presents a certain analogy with that obtained by means of the interrupted direct current. The physiological reaction, however, shows an important difference.

When we use a galvanic current, an increase in the intensity of the latter causes, as has been seen, constantly stronger and more sustained contractions until finally tetanus is produced.

With the induced current the contractions are rapid and isolated. If we proceed to increase the intensity of the current, we get stimulation through a more extensive zone; the contraction, to a certain extent, takes in more territory, but it does not give rise to tetanus.

With the kinds of induction-apparatus used in practice a contraction commonly occurs, whether we use the positive or the negative pole as our active pole; but when we have got a clearly marked reaction with the latter, we have to increase the intensity of the current a little in order to excite an equivalent reaction with the positive pole.

Excitation of the muscles by the induced current is more interesting in practice than that of the nerves. The reader is aware of the important part which, since the labors of Duchenne, it again plays as a therapeutic method. It also renders great service from a diagnostic point of view.

The bipolar and the polar methods are employed.

To perform bipolar stimulation we place both electrodes along the course of the muscle. Duchenne has recommended that they be applied as near as possible to the points where the nerves enter the muscles. If we follow this advice, we find ourselves in the midst of complex conditions, which may, however, have their practical utility. We get at the breaking of the current a well-marked instantaneous contraction, which is transformed into a tetanus as soon as the interruptions reach the number of 40 a second.

When we employ unipolar stimulation the negative pole still shows itself more active than the positive. Under the conditions ordinarily found in practice we get at the breaking of the circuit a contraction both with the positive and with the negative pole, but in the latter case the effect is more energetic.

The determination of the current-intensity absolutely necessary to excite a well-marked contraction is very important, both for purposes of diagnosis and treatment. For diagnosis we thus get a better estimate of the modifications which may occur during stimulation by the induced current, and in treatment we, by this means, avoid the disagreeable effects resulting from overstrong excitations. This object can be readily attained when the form of apparatus with a sliding-stand is used.

The sensory nerves are strongly stimulated by the induced currents, and these currents might be utilized oftener than they are in practice when it is a question of determining the condition in which the cutaneous sensibility may happen to be.

In describing the phenomena, we must distinguish between the effects produced by stimulation of the cutaneous nerves and those which are caused by stimulation of the nerve-trunks.

In the skin each induced wave gives rise to a sensation which is compared to a slight prickling. When the spring of the interrupter vibrates freely we get a continuous sensation, and even a painful sense of burning, especially if we make use of the current from a coil with long fine wire.

When the skin and the electrodes are dry the painful sensation becomes one of the most distressing that we can have; it reaches its greatest intensity when the electrode is a metallic brush.

After excitation, the cutaneous sensibility remains modified for some time. Directly after the application the tactile sensibility is diminished; later, on the coutrary, it is slightly exalted. If the

metallic brush is used, the diminution in sensibility which follows is more persistent, and is replaced but slowly by a hyperæsthesia which sometimes lasts for a whole day. When application with the brush has been renewed several times the resulting hyperæsthesia may last for several days. Hence, Rumpf, Engländer, and Vulpian have utilized this method in order to combat cutaneous anæsthesia.

The application of the electrodes in the region of the nerve-trunks gives rise to a sensation of prickling and numbness, which radiates toward the periphery. The negative pole is in this case more active than the positive. Lastly, the pain is the more intense the more frequent the interruptions are.

Stimulation of the cutaneous nerves by induced currents is a powerful means of producing revulsion, which, since the time of Duchenne, has often been made use of. Of the remote phenomena produced in a reflex way we will mention only the most important. Feinberg has observed, as a result of stimulating the skin with the metallic brush, cerebral anæmia followed by cerebral hyperæmia. In the experiments made by Rumpf the hyperæmia is produced in the cerebral hemisphere of the side opposite to the point stimulated. According to von Basch, excitation of the skin of the abdomen with the metallic brush causes abdominal plethora, and a cerebral anæmia which may induce syncope.

To complete what has been said upon the subject of general sensibility, it is necessary to recollect the fact that, according to Duchenne, there is a muscular sensibility proper, or rather an electro-muscular sensibility. At the moment when the muscle contracts, under the influence of the electrical stimulus, the subject experiences a dull, deeply situated sensation, the intensity of which is in proportion to the energy of the contraction. When the muscle is tetanized this sensation is, in general, the same as that of a painful cramp.

The special senses have been studied only with the galvanic current. There is, therefore, nothing of interest to speak of regarding the faradic reactions of the organs of special sensibility.

Some observations made upon the secretory and vasomotor nerves deserve mention. Cutaneous faradization performed with a metallic brush gives rise to local sweating, more or less marked according to the region affected. Is this the result of the direct stimulation of the sudorific nerves? As has already been said, faradization with the brush constitutes one of the most active of revulsive measures, and hence the sweating may be produced in a reflex way, and in

estimating the result we must take this property of the application into account, even when it seems to be solely a question of a local effect.

However this may be, we have already, when studying thermic agents, cited facts which prove that the sudorific nerves respond to faradic stimulation. Thus, Adamkiewicz obtained abundant sweating in the plantar region by faradizing the tibial nerve in the popliteal space.

Numerous experiments made upon animals authorize the belief that it would be easy to stimulate various secretions by means of faradization. As regards the lacteal secretion, it has been increased by weak currents, as has been done by H. Pierron, the negative pole being placed beneath the breast, and the positive being placed upon the nipple and carried to and fro over the gland.

The effects of faradization upon the vasomotor nerves has been but little studied. Tripier made observations showing with absolute certainty that faradization of a determinate region is accompanied by over-activity of the circulation and the development of arterial pulsations, and that these phenomena cease as soon as the electrization is interrupted. But in such cases the effects are complex, for we act upon several organs at once—namely, upon both vessels and nerves, while at the same time we stir up reflex actions. It is probable enough that it is by means of this last-named mechanism—*i. e.*, by a reflex channel—that we produce vaso-dilatation.

The effects observed upon the blood-pressure and the general circulation appear likewise to be of reflex origin.

When we perform faradization in the region of the neck we get dilatation of the pupil upon the corresponding side and a modification of the temperature, that of the cheek becoming somewhat lowered after from two to twelve minutes. Stimulation of the nerves of the limbs, such as the ulnar and peroneal nerves, likewise, as Eulenburg and Przewoski have demonstrated, causes a lowering of temperature in the corresponding limbs, soon followed by an elevation of 0.5° above the normal. All these effects seem to result from the stimulation of the sensory cutaneous nerves rather than the direct stimulation of the vasomotors. They come, therefore, at least in part, under the head of revulsion.

In the neck we find, moreover, the vagus and phrenic nerves. These can certainly be affected by the faradic current.

Stimulation of the vagus may produce a contraction of the mus-

cles of the larynx and cause movements of the stomach and intestine. Brenner has seen vomiting or efforts at vomiting occur. Gerhardt has succeeded in stimulating the laryngeal branches. If we place the active electrode upon the level of the superior cornu of the thyroid cartilage, we can readily set the superior laryngeal nerve into action. It is more difficult to reach the inferior laryngeal nerve, although we can do it by applying the electrode at the level of the inferior border of the same cartilage. Nevertheless, extra-laryngeal faradization is efficacious enough to serve as a substitute for intra-laryngeal faradization, and the numerous therapeutic results obtained by many practitioners now put this fact beyond doubt.

It is important to know that through the medium of the vagus we can reach the heart and cause it to stop beating, for this constitutes one of the dangers in performing faradization of the phrenic in the neck (H. A. Hare and Edward Martin), a procedure which has been often resorted to in cases of chloroform asphyxia.

But while the heart may be influenced indirectly through the medium of the vagus, it may, according to the observations of von Ziemssen, be regarded as itself insensitive to induced currents. These observations were made upon a subject whose ribs had been resected, the conditions being, therefore, those under which, as we have seen, the galvanic current produces an effect.

The stomach and intestines are often subjected to faradic stimulation. External faradization properly made is certainly able to excite contractions of the stomach. Nor is it without effect upon the intestine also, although in general the latter organ reacts less distinctly than does the stomach.

Internal faradization gives more complete results. We can get manifest and rapid reactions at the rectum or sphincter ani, and it is also established that the stomach responds distinctly to stimulation carried directly into its cavity.

A diminution in the size of the spleen has been obtained in animals by faradization, either of the nerve trunks distributed to it or of certain peripheral nerves (Mosler and Jerusalimsky). Among the latter may be mentioned the sciatic, which has been previously divided (Tarchanoff), and the vagus (Oehl). In man faradization of the splenic region, done with a therapeutic object, has given inconstant results. Side by side with various fruitless attempts, quite a large number of successes have been enumerated.

The urethra and bladder are sensitive to faradization. The same

is true of the uterus, although the latter organ appears to be more readily stimulated by the interrupted galvanic current.

Faradization always entails an increase in the size of the contracted muscle, whether the latter be striated or smooth. At the same time it causes an elevation of the temperature of the muscle, even when it does not cause a sharply marked contraction. Galvanization, on the other hand, produces heat only when there is a contraction of the muscle.

As a correlative of this, d'Arsonval has observed exaggeration of the respiratory combustion following faradization, while, it will be remembered, galvanization remains inactive in this regard.

Thus a very gentle faradization, when generalized, may entail a modification of tissue-metamorphosis and increase the production of heat when the conditions are such that no apparent muscular contraction is seen to be produced. This is what is particularly observed as a result of the faradic bath, which produces a simultaneous stimulation of the muscular and the sensory nervous system.

When the muscular contractions are extensive and tetanic, the elevation of the central temperature may be considerable. Electrical tetanus may thus, as Charles Richet has shown, even result in death through hyperthermia.

There is a certain difference between the physiological properties of the extra-current and those of the induced current. The results obtained by Duchenne in this respect are as follows :

The induced current differs from the extra-current in its more lively action upon cutaneous sensibility, its superiority in producing reflex contractions and stimulation of the retina, and by the greater depth of its penetration into the tissues, when the rheophores are moistened.

The extra-current has the advantage over the other when it is a question of stimulating certain superficial organs, such as the muscles or mixed nerves and the testicles, or various hollow organs, such as the bladder and rectum.

The difference between the two is the more appreciable in proportion as the intermissions are more rapidly repeated.

Duchenne used very frequent intermissions. At present we often make use of intermissions that are less frequent, and it has been discovered that the latter are better adapted for performing faradization of muscles and of some organs containing smooth muscular fibres. For instance, Danion does not care to have more than from one to

three intermissions a second in order to stimulate the intestine and bladder.

Cuno Weil has stated that there is no marked difference between the electromotive force of coils with fine wire and coils with coarse wire, the self-induction diminishing greatly the electromotive force of the long-wire coil. The coarse-wire coil, the resistance of which is low, should, according to him, be preferred in all cases in which there are no great resistances to overcome, and hence is to be employed for stimulating the motor nerves and the muscles where moist electrodes are used. On the other hand, the fine-wire coil must be used for overcoming great resistances, *e. g.*, for stimulating the cutaneous sensibility by means of dry electrodes.

Effects Produced by Static Currents. Static charges from the Leyden jar or in the form of sparks from static machines produce effects analogous to those which we have just described in speaking about induced currents. We may, with the electricity of the static machine, as well as with that of the coil, get modifications of cutaneous sensibility and excite direct or indirect contraction of the muscles. Static electricity presents, moreover, the advantage that contractions can be had when the electrization is made through the clothing. It constitutes, as Schwanda has stated, the surest means of reaching a muscle without the stimulus being propagated to the neighboring muscles. Lastly, the muscles in certain pathological conditions still respond to the static discharge, although their faradic excitability, and sometimes their galvanic excitability, too, have disappeared.

We have just studied the effects obtained by the variable electric states produced by means of the galvanic current, the various kinds of induction-apparatus, and the various kinds of static apparatus.

The facts that we have enunciated with regard to the stimulation of nerves and muscles seem to show that the effects of this stimulation vary with the source of the electricity. This question, which has for a long time occupied the attention of physiologists, has given rise in recent years to some interesting works. These tend to demonstrate that the effects of the stimulation of nerves and muscles are dependent, on the one hand, upon the physical method of applying the electricity, and, on the other hand, upon the modifications produced in the tissues by the passage of the current or by the continuous state established in the interval between the passage of multiple charges.

D'Arsonval has denoted the physical method of applying the current by the name of *stimulation-characteristic.* By means of an ingenious apparatus he has succeeded in obtaining a graphic trace, in the form of a curve, of the excitation produced by any method whatever, and of recording beneath it the physiological reaction. He has drawn from his researches various conclusions, the chief of which are as follows:

When we stimulate nerves and muscles we may induce the same physiological reactions, whatever be the source of electricity employed, provided that the discharge has *the same form in the given time.*

The excitability of a nerve is set in action mainly by the rapidity and amount of the variation in the potential, the quantity of electricity in this case playing only a secondary part. A muscle, on the other hand, requires a less abrupt variation of potential in order for it to begin acting. If it is necessary to use a more intense current for its stimulation than for that of the nerve, this depends, according to d'Arsonval, upon the fact that the muscle, being a better conductor than the nerve, requires the calling into action of a greater quantity of electricity for the same difference of potential between the extremities of the tissue stimulated.

It can be seen that, from d'Arsonval's point of view, the stimulation takes place at the point of application of the positive or negative electrode. G. Weiss has combated this opinion. He thinks that he has demonstrated that the stimulation is produced at all points through which the current passes, and that, consequently, it is necessary to know the intensity that the current possesses at each instant. From d'Arsonval's point of view, the important element to consider in the case of the electric stimulation of the nerves and muscles is the potential and its variations at the point of application of the electrodes; from Weiss's point of view the important element is the intensity of the current and its variations.

However it may be with this point of pure physics, which is still under discussion, with regard to the manner of calculating the value of the agent which is made to act upon the nerves or upon the muscles, it is admitted that all discharges obtained with the galvanic current or with induction-apparatus modify the properties of the nerves by producing polarization. This important fact, already called in by various physiologists to account for the phenomena, has been demonstrated by the researches of Charbonnel-Salle. It is through this polarization of the tissues that it becomes possible to explain the

apparent contradictions noticed in the laws previously formulated, and especially in those of Pflüger.

The induced current is less of a polarizer than is the galvanic current; but it has the disadvantage of being more difficult to measure. Hence Marey, Chauveau, d'Arsonval, and Boudet de Paris have tried to replace it by discharges from the tinfoil condenser. The last-named electrician has used the condenser upon man, and has drawn up a table which enables one to discover the energy of the discharge without its being necessary to make any calculation. At present gauged condensers are made so as to admit of their capacity being varied in a determinate manner. One is then supplied with tools that enables him to work either for physiological researches or for medical applications under conditions which are very precisely mapped out.

When we wish to make a unipolar stimulation in man with the condenser we place a large plate connected with the positive pole upon the dorsal region and apply a small plate or a pad having an area of about twenty square centimetres, and connected with the negative pole, to the region occupied by the organ to be stimulated.

According to Boudet de Paris, discharges from the condenser do not give rise to polarization. When he stimulated a frog's muscle with discharges repeated every ten seconds, the tracings showed that the last twenty excitations gave the same result as the first twenty.

Furthermore, to render any kind of chemical polarization impossible, Boudet de Paris has devised with the aid of two condensers an arrangement which enables us to make the discharges alternating.

D'Arsonval has denied the advantages possessed by the condenser. According to him, the value of a given stimulation would not be sufficiently determined when simply the capacity of the condenser and the difference of potential between the armatures are known. We do get, it is true, with these data the measure of the energy set free by the apparatus at the instant when it is discharged. But there is no relation between the energy (work) of an electrical excitation and of the muscular contraction which results from it. It is possible to demonstrate this interesting fact in various ways.

D'Arsonval charges a condenser having a capacity of $\frac{1}{10}$ with a potential of 10, and discharges it into a frog's leg arranged as a galvanoscope. He gets a violent contraction. He repeats the experiment, using this time a condenser having a capacity of 10, but charged with a potential of 1. The discharge in this case gives rise

to but a slight contraction, and may even remain without effect. Yet the energy of the excitation is the same in both cases.

On the other hand, it results from the experiments of Charbonnel-Salle that the discharging currents produced by condensers do not abrogate polarization. Every discharge taking place in a determinate direction has the property of acting upon the nerve in the same way as does the galvanic current. This would be the case for a single application of electric action, and, *à fortiori*, would be true when successive applications in the same direction are brought into play.

We must state, however, that these remarks apply to stimulation of a nerve, while the researches of Boudet de Paris bear upon the stimulation of muscle, which appears to be polarized less, or at least to be less modified under the influence of a weak polarizing action.

However this may be, d'Arsonval has devised two arrangements which suppress all polarization effects, and to which he attaches great importance, even from a potential point of view.

In 1881, when seeking to solve the problem of how to stimulate nerves, he conceived the idea of passing the discharge of the condenser into the primary wire of an induction-coil deprived of its soft-iron core. The instantaneous current induced in the secondary wire serves for the stimulation of the nerve.

It is easy to understand the physical change that takes place during the discharge of the condenser, the primary circuit (inductor) is traversed by a wave of electricity, which, starting from zero, rapidly increases, and at the expiration of a very short time falls to zero again. There are, hence, produced in the secondary wire two inductions in an opposite direction, the first during the period of increase of the current, the second during the period of decline. The nerve thus in a very short time is traversed by two waves of electricity, a positive and a negative one. The excitation no longer takes place in the same direction; polarization is suppressed, or, to speak more precisely, two polarizations are produced to neutralize each other.

This procedure, which has been put into practice by Mendelsohn, has the advantage of suppressing any development of fatigue and of furnishing contractions that are regular and equal, whatever their number.

The second arrangement devised by d'Arsonval would solve the problem of how to produce stimulation of a muscle. The discharges of induced currents, being very brief and of high potential, are particularly adapted for stimulating the terminations of the sensory

and motor nerves. Their duration in the ordinary forms of apparatus does not exceed three-tenths of a second. If we proceed to prolong this discharge, we get to a point at which, in accordance with the propositions previously enunciated, we can no longer produce excitation of nerve-tissue; while, on the other hand, we get conditions that are the most favorable for excitation of muscular tissue.

This being granted, suppose we take a coil with quite coarse wire, so as to have quantity, and we retard its discharge. With this end in view we intercalate, as a derived circuit in the secondary coil, a condenser having a capacity of a microfarad. We thus get contraction of a muscle without its causing pain, an effect which we are accustomed to require of the galvanic current.

D'Arsonval attaches great importance to this procedure, either when it is our intention to produce stimulation of the muscles without causing pain, or when our object is to study the modifications of muscular excitability for diagnostic purposes.

The only thing left in order to complete the study of this subject is for me to point out to you the principal effects produced by alternating sinusoidal currents.

D'Arsonval's apparatus, which we have previously described, has been made use of by Tripier. When rotated gently by hand it does not excite any sensation at all during the passage of the current. When the rapidity of rotation of the wheel is accelerated the subject feels pricklings of the skin. When the rotation becomes still greater vague muscular sensations are superadded, which may become quite pronounced.

The sensations and the contractions produced are a function of the rapidity of rotation.

When working upon animals we may get a contraction of the smooth muscular fibres, even when we cannot produce any apparent reaction in the striated fibres. We may also remark that this kind of electrization, according to experiments which have been made by d'Arsonval upon man and animals, is followed by a marked increase (one of more than one-fourth) in the amount of respiratory combustion, and that even when the passage of the current gives rise neither to any apparent muscular contraction nor to symptoms of pain.

The question of the employment of sinusoidal currents is still under study. Gautier and Larat, in order to obtain currents of this

sort in their office, have conceived the idea of utilizing the currents furnished by the dynamo-electric machines designed to supply the electric lights of the city.

Electrotherapeutics. Being now acquainted with the principles of electrophysics and electrophysiology, we may now start upon the study of how to apply the different procedures for producing electrization.

The first attempts were made, as you know, with frictional electricity, which enabled those who used it to get very diverse results, and even general modifications of nutrition.

Later, this variety of electrization was given up, and was replaced in Germany by discontinuous galvanization, championed by Remak, and in France by faradization, which was carried to a high degree of perfection by Duchenne. In recent years franklinization has been restored to honor, and at present it occupies an important place among therapeutic procedures.

Franklinization. The instruments necessary for applying static electricity consist of a good influence-machine, an insulating-stool, and one or more conductors and dischargers of various shapes.

We have already recommended for medical uses the Carré machine or that of the Wimshurst type, modified by Gaiffe. These machines may be run by hand. But the physician should avoid having recourse to an assistant, whose presence is often inconvenient. It is necessary, therefore, to obtain the mechanical energy that we need as far as possible from a motor.

At La Salpêtrière a steam motor, placed in the cellar, runs a dynamo-electric machine, which works an electric motor set within the glass case that protects the machine. Such an appliance is too expensive for the practitioner who treats only a limited number of patients with electricity. It is much simpler to have a battery of bichromate cells, or of accumulators, to work a small electric motor, which is connected with the pulleys that turn the plates. We may also employ a water or air motor.

The work that we wish to produce being only 5 or 6 kilogrammetres, there is no use in employing a gas motor giving half a horse-power.

In localities where the physician can make connections with a central electric plant, an electric motor connected with the system of wires extending from the works will supply him in a very simple manner with the power that he needs.

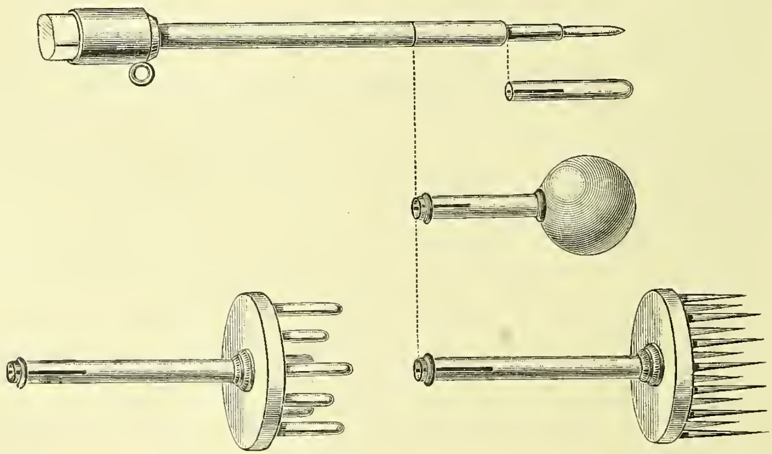
The insulating-stool is formed of a single board, with well-rounded edges, mounted on legs made of glass and covered with shellac. These legs, particularly in damp weather, ought to be wiped off with warmed cloths. We may also follow Danion's advice and insulate the patient by means of a thick plate of caoutchouc.

The stool upon which the patient is placed is connected with the machine by means of conductors. The form and dimensions of the conductors vary with the needs of practice. Most often we make use of brass rods ending in hooks, which enable us to attach the rods to a ring mounted on the collector of the machine.

The dischargers are the accessory instruments which enable us to draw sparks from the patient's body, or to produce friction, the breeze, and the aura.

The ordinary discharger may subserve various ends. With this object, it is composed of a shaft of insulating substance (glass, hard rubber), ending in a metal cap which carries a hook and a screw-

Fig. 83.



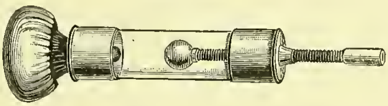
thread. (Fig. 83.) We may attach to the hook a trailing chain, which passes through a metal ring mounted on an insulating shank. Upon the end of the discharger may be screwed spheres or points of metal or wood, according to the requirements of the case.

The electrician holds the discharger in his right hand, and by means of the shaft bearing the ring, which is held in his left hand, directs the ground-chain of the machine so as to prevent its touching

his body or the patient's. Dischargers of wood are preferred when it is wished to moderate the intensity of the effect.

In order to get sparks having always the same length, Boudet de Paris has had a discharger constructed (Fig. 84) formed of a charcoal knob, covered with moist chamois-skin, and connected with a metal ball which is lodged in a glass tube. A second ball, mounted on a shank, can be plunged more or less deeply into the interior of the same tube, so that the distance between the two balls can be modified at will. The shank which carries this second ball is connected with the ground. In case it is desired to produce the aura, the ball is replaced by a blunt point.

FIG. 84.



Benedikt uses a special discharger, known under the name of the electric bell. It is composed of a hollow hemisphere with sharp edges, connected with the ground, and placed over the head of the patient, who is insulated by being placed upon the stool. The borders of the bell act like points. Hence, Chardin has replaced the bell by a metal disk provided with many points.

Under some circumstances it is necessary to subject a certain region of the body to the prolonged action of electricity. The dischargers are then kept, by means of insulating supports, in the vicinity of the points to be electrified.

The different kinds of electrization that we can get by means of these instruments were described by Mauduyt in his treatise, which is dated 1784. All that has been added is the electric douche.

The procedures employed are the electric bath, the static breeze or the souffle,[1] sparks, electric douche, electric friction, and concussion.

For the electric (or electrostatic) bath the patient is placed upon the stool, which is connected with one of the poles of the machine by means of a conductor, the other pole being connected with the ground. We must recollect that the electricity thus produced is not in equilibrium, but in motion. When the connection is made with the collector of positive electricity a continuous current is established from the machine to the stool, from the stool to the patient, and from

[1] A feeling of coolness by bringing a metallic ball within six inches of a person charged with static electricity.—ED.

the patient to the air about him and to the ground. The direction of the current is opposite when the bath is electronegative. The escape of electricity is facilitated by the numerous points presented by the surface of the patient's body.

According to R. Vigoroux, the resistance of the patient will be a factor here as in galvanic electrization—*i. e.*, the less the resistance the greater is the intensity of the current, other things being equal. In Basedow's disease this resistance is greatly diminished; patients with this affection cannot stand the electrostatic bath, while hysterical subjects, whose resistance is great, can remain in connection with the machine for hours. Hence, R. Vigoroux advises that the electrical resistance of the patient should be determined before any treatment is employed. These remarks are of practical interest; but they presuppose that static electricity passes through the body in the same way as does the galvanic current, and this does not seem to us to have been proved.

The positive bath is the one most generally employed. The duration of the sitting varies from a few minutes to an hour, depending upon the nature of the disease that we wish to combat and upon the impressionability of the subject.

When the sitting is finished we stop the machine, or, better, put our foot upon the stool so as to bring its potential back to zero, thus avoiding the discharges or sparks that might be produced at the instant when the patient gets down from the stool.

The electric wind or breeze is obtained in the following way: while the patient is on the stool, which is connected with the machine, we bring toward him, on a level with the part upon which we wish to act, the discharger, which is furnished with one or more points, and is kept at a distance of 3 to 5 centimetres. The electrified air is repelled by the point and attracted by the patient, who is charged with electricity of an opposite sign. There is thus produced a movement of air or a breeze, giving a sensation of a draught of air. According to R. Vigoroux, the positive pole produces this sensation more readily than does the negative pole. It would be better, then, in cases in which one makes use of this method to give the patient an electronegative bath. When the application of the breeze is going to be a prolonged one, the discharger is put in position and attached to the support previously described.

The electric breeze possesses incontestable sedative properties. It is employed principally in painful diseases.

When, with the patient arranged as in the preceding case, we carry toward his body a wooden or metallic point that is blunt instead of sharp, we get what is called the aura. The point is kept at a distance of 2 to 3 centimetres, and the aura, which is visible particularly in the dark, varies according as it is positive (when it has a violaceous gleam) or negative. The violaceous gleam is accompanied by a peculiar crackling ; it has a rubefacient action, adapted for producing revulsion.

When the discharger ends in a ball and is close enough to the body, we see a spark leap across between the ball and the patient. The quantity of electricity which is present in the discharge is in proportion to the size of the ball. We can vary the amount of energy employed, and, consequently, the effects produced, by varying either the distance of the discharger or the size of the ball. If we desire to weaken the effect produced, we can withdraw a part of the charge from the patient by carrying the point or the chain of the discharger nearer the stool.

The spark discharge is principally used to produce excitation of the nerves and muscles. The knob-discharger of Boudet de Paris is to be recommended when we wish to get a well-localized action.

If we proceed to pass the ball of the discharger over the surface of body (resting it upon the clothes), we get electric friction. Sparks which are very short, but are quite often very painful, leap between the discharger and the skin. A burning sensation results, which is the more acute the slower the friction is performed.

The form of application known as concussion, which was used by the first promotors of static electrization, is now abandoned.

The electric douche, which has been made use of mainly by Benedikt and Stein, is in reality only a variety of the electric breeze. The bell should be placed above the head and high enough so that no sparks shall be thrown out. German physicians attribute to this procedure sedative effects particularly adapted for combating persistent insomnia.

The physician possesses in the various methods a sort of sliding scale of measures, enabling him to get effects that are more or less intense. He should make all of them cautiously and in a gradually progressive manner. At the outset the sittings should be short, lasting not more than from three to five minutes. Some practitioners go on, and finally bring their patients up to the point where they can stand the electrostatic bath for hours. It is rarely proper to prolong the duration of the sitting beyond half an hour.

At the outset of the treatment the sittings should be had daily. Later, when the effect produced is lessened, or when the amelioration becomes marked, the sittings are placed further and further apart, only one or two being had a week. It is usually advised to suspend the treatment during the menstrual period, except when the treatment consists simply in the administration of the electrostatic bath.

GALVANIZATION forms at present the means of applying electricity that is most often made use of in medicine.

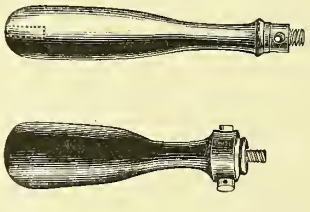
We have already studied the subject sufficiently to be able to describe in a few words the different procedures which it comprises. These methods are: continuous galvanization and interrupted galvanization, the latter including the labile method of the Germans, and interruptions, properly so-called, produced by making and breaking the current. With these various procedures must also be grouped the employment of abrupt reversals of the current—*i. e.*, what are called Volta's alternating currents.

The reader is acquainted with the instruments required for applying galvanization under good physical conditions. The only thing left to speak of particularly is the electrodes, which we have had no occasion as yet to describe in detail.

The electrodes which are most extensively in use are the cushion and the plate electrodes.

The cushion electrodes are screwed on an insulating-handle of wood, hard rubber, or celluloid, which is held in the hand (Fig. 85), and

FIG. 85.



which is furnished with a metal cap in which is hollowed the cavity for the reception of the end of the rheophore. This cap ends in a screw whose nut forms a part of the electrode proper; there is sometimes added to it an interrupting-button, which when pressed upon breaks the current. The ordinary cushion has a knob made of carbon, which is a good conductor, attached to the nut that is screwed into the electrode-handle. This carbon is covered with very supple

chamois-skin. Its dimensions vary greatly. We may give it a mushroom-shape and cover it with sponge, which is preferable to using a sponge inserted in a metal tube.

To get electrodes of very small surface we screw into the handle a metal shank curved upon itself, covered or not with some insulating material, and ending in an olive-shaped knob of carbon covered by chamois-skin. Bare metal electrodes are rarely used.

Fig. 86.

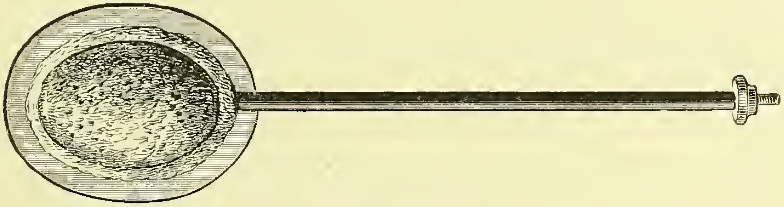
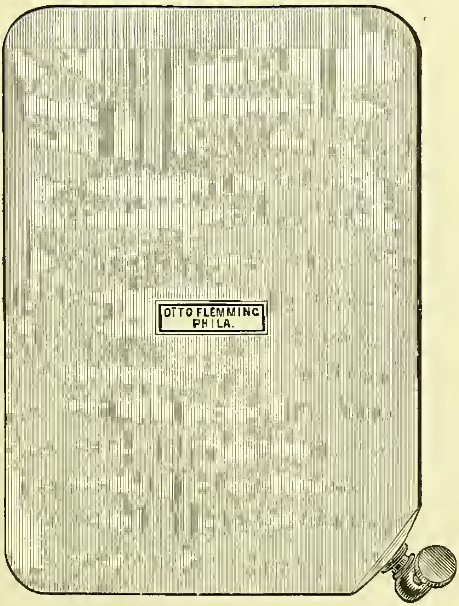


Fig. 87.



The plate-shaped electrodes are almost always placed upon a fixed handle (Fig. 86). They are formed of a sheet of tin, usually pierced with holes, which render it easier to moisten the electrodes, and they are covered with chamois-skin or sponge. The tin plate bears a small metal cap which is perforated and furnished with a screw to which

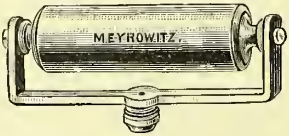
is fitted the end of the rheophore wire (Fig. 87), or, better still, it is attached to a bifurcated end.

The forms and dimensions of these plates vary greatly according to circumstances; but it is indispensable that we should know their surface in square centimetres, so as to be able to estimate the density of the current at the point where they are applied.

The electrodes should always be well moistened before being applied to the skin. With this end in view, they should be dipped some minutes before they are used in warm water.

In cases in which we wish to perform labile galvanization we make use of a roller-shaped electrode (Fig. 88), so mounted that it can be moved about over the surface of the body.

FIG. 88.



The indifferent electrode may be replaced by a basin or tub of water, in which the patient plunges his hand or foot, the water being connected with one of the poles of the battery by means of the rheophore wire.

A great number of other electrodes have been devised having special uses, which we shall presently describe.

Continuous galvanization comprises the bipolar and the polar methods.

In the bipolar method the electrodes have the same area, and are so placed as to make the current pass through a segment of the body or of one of its members. We have already pointed out the principles which should serve as our guide in this kind of electrization. Sometimes we make the current take the same direction during the entire period of the sitting; sometimes we reverse the current at a certain moment and thus make an alternating electrization.

When it is impossible, even with large electrodes to make the current reach the entire extent of the organ that we wish to modify, we advance by sections, changing the place of our electrodes at the end of some minutes.

To employ the polar method we place a large plate, called the indifferent electrode, upon a point, such as the sternum, tibia, or epi-

gastrium, that is not very sensitive, or, better still, we immerse one of the limbs in a basin, while the active electrode, which is small, is applied in the vicinity of the point where we wish to localize the action.

In all cases we should take care to begin by applying well-moistened electrodes and to satisfy ourselves that the contact is uniform in all parts before we send the current through the circuit. To hold the electrodes in place we use bands or straps. Sometimes we may cover them with a napkin, upon which the patient presses strongly with his hand. We start the current, when at the expiration of some minutes the skin at the site of the electrodes is well moistened, and we advance by degrees and without causing shocks until we have reached the current-intensity that we wish to use.

To change the direction of the current we first bring the latter down to zero and then slowly increase its intensity, but, for reasons that have already been stated, do not pass all at once to our former pitch of intensity. Similarly, when there is an occasion for performing electrization of successive parts of the body we should reduce the current to zero before changing the place of the electrodes.

The name of labile galvanization is given in Germany to a method which consists in passing one of the electrodes over the surface of the part to which we are making an application, the other electrode being kept fixed upon a point of election. The rolling electrode, which is more or less large and varies in shape, ought not to leave the skin· Hence, no effects due to breaking and closing the circuit are produced, but the displacement of the electrode causes a constant variation in the intensity of the current and gives rise to a variable state, which, to be sure, is ill-defined and whose effects are intermediate between those of continuous and of interrupted electrization. In fact, this kind of electrization produces at the same time a stimulant action upon the muscles and nerves, and a more or less intense trophic action (catalytic action of R. Remak).

If we have to perform labile galvanization of a part (on the extremities, for example), we apply a large fixed electrode either upon the corresponding segment of the spinal cord or at the site of the nerve-plexus supplying the affected limb. This electrode is connected with the positive pole. The negative pole under the form of a rolling electrode is passed along the nerves or over the muscles and the motor points. We thus carry the electrode upon the region to which

we have to apply the electrization in thirty or forty different radiating directions without ever breaking contact with the skin.

Interrupted galvanization consists essentially in the production of openings and closures of the circuit made during the course of a continuous electrization. This method is most often employed in the polar application, since it is of especial service in stimulating nerves and muscles.

The interruptions may be produced in various ways, either by raising the electrode from the skin and then replacing it, or by breaking the circuit with an interrupting-button, the breaking being followed by a renewed closure when we stop pressing upon the button. When working with fixed electrodes we can have the circuit made and broken at regular intervals by means of the metronome.

Interrupted galvanization represents the method of election when it is desired to combine the chemical effects produced by the continuous state with the stimulant action due to the variable state. It may be applied in quite different ways, according to the nature of the case in hand.

We have seen that in using the galvanic current we must necessarily concern ourselves quite as much with the density as with the intensity of the current; *i. e.*, with the conditions expressed by the formula

$$D = \frac{I}{S},$$

(D, the density of the current; I, the intensity in milliampères; and S, the surface of the electrode in square centimetres).

The author has already pointed out what, according to Boudet de Paris, should be the minimum area of the active electrode for any given current-density, and the data empirically determined by this skilful electrician may serve as our guide in practice. But we ought still to regard this question from quite another point of view, in regard to which we must now speak a few words.

It has been asked what would be the most suitable density to use in various cases. This question has been discussed mainly by C. W. Müller. According to this author, the mean current-density ought, under ordinary conditions, to be $\frac{1}{18}$, or 1 milliampère for an active electrode of 18 square centimetres. The densities $\frac{1}{18}$, $\frac{2}{36}$, $\frac{3}{54}$, $\frac{4}{72}$, $\frac{5}{90}$, $\frac{6}{108}$, etc., being equivalent, it is easy to establish a relationship between the area of the active electrode and the current-intensity for the case in which we wish to apply electrization with a mean density of $\frac{1}{18}$.

C. W. Müller advises us to work with a greater density, such as $\frac{1}{14}$, $\frac{1}{10}$, or even $\frac{1}{6}$, in torpid cases; *e. g.*, when we wish to modify the character of a chronic arthritis.

If it is a question of stimulating the peripheral nerves with the positive electrode, we shall make use of a density of $\frac{1}{9}$, and we may employ a higher density still in cases of lumbago.

For labile or interrupted galvanization of the upper extremities, the suitable density is $\frac{1}{6}$; it may be carried as high as $\frac{1}{5}$ for the same manipulations when performed upon the lower limbs, particularly when there is quite a large resistance to overcome. Stimulation of the genital nerves requires a density of $\frac{1}{10}$.

In cases of nervous erethism (hysteria, neurasthenia) or in inflammatory lesions, and certainly when the subjects are very sensitive to the action of electricity, we should use only weak densities (of $\frac{1}{35}$ to $\frac{1}{45}$).

Lastly, we may add from the same author the following values for the densities which are to be used in certain regions: For electrization of the brain the density ought to be from $\frac{1}{30}$ to $\frac{1}{24}$; for electrization of the medulla oblongata from $\frac{1}{24}$ to $\frac{1}{20}$; and for electrization of the neck the density should be from $\frac{1}{30}$ to $\frac{1}{28}$; and the duration of the sitting from 30 to 40 seconds. When we wish to get cerebral anæmia and sleep, on the other hand, the density should be increased to $\frac{1}{7}$ and kept up from 2 or 3 minutes in cases when we wish to secure vascular dilatation.

For electrization of the head, Lewandowski recommends still lower densities.

When we perform electrization with electrodes of the same or almost the same area, the current-density is determined by the area of one of the electrodes, if this is applied near a diseased point that is situated superficially. In the opposite case, when the diseased point is deeply seated, and also when both electrodes are applied to points at which the morbid conditions are appreciably the same, we take, in order to determine the density, the arithmetical mean of the areas of the two electrodes.

While these data are empirical, it is important to keep them in mind, for the general tendency is to use currents that are too intense.

The duration of the electrization is subordinated strictly to the density of the current employed; it should be the shorter the greater the latter is, and *vice versa*.

For electrization of the brain and of the sympathetic, Lewandowski thinks that the duration of the sittings should be one minute; for electrization of the cord, three minutes. Labile galvanization should last the length of time that it takes to pass forty times over the affected region.

In the other methods of electrization the duration of the sittings varies according to different circumstances; it is most frequently from five to ten minutes. We shall have occasion to return to this point when considering the procedures which are left for us to describe. For the present we will simply say that currents of short duration act as stimulants and restoratives; and that, on the other hand, currents of long duration are paralyzers or anti-spasmodics.

The frequency of the applications should in general bear a relation to the mode of development of the disease. In the case of neuralgias or rheumatic manifestations, one or two sittings a day are indicated. When the cases are acute and of rapid development, five or six sittings a week may be had; while in chronic cases, from two to four sittings are sufficient.

FARADIZATION. We do not need to dwell upon the way in which faradization is applied.

Among the varieties of medical apparatus which have been described, one must select, as far as possible, one with a sliding-stand, which will enable him to graduate the intensity of the currents better than other kinds will, and to make use of currents furnished by wires of different sizes and lengths. In default of an apparatus of this sort, we must at least be able to avail ourselves of the extra-current and the current of a coil with a fine long wire. We must likewise be able to vary the number of interruptions at will. For infrequent interruptions a metronome is the most precise instrument and the one least subject to derangements.

FIG. 89.

Bipolar faradization is performed with two knob-electrodes of medium width, which are applied at but a short distance apart, and may often be held in one hand. In place of these electrodes hollow metal cylinders, called hand sponge-holders (Fig. 89), may be employed.

Polar (or unipolar) stimulation is performed in an analogous way to that which we have described for galvanization. The indifferent pole is in general connected with a plate that is not so large as that used in galvanization. The active pole may be connected with a small plate or a knob-electrode.

When used for stimulating the motor nerves and the muscles the plates are moistened. They should be left dry when the attempt is made to stimulate the sensory nerves of the skin and to get an effect by reflex action. We obtain more powerful effects still by means of the electric brush. In this kind of stimulation we place a damp plate-electrode upon an indifferent spot and keep it fixed there, and pass a dry knob-electrode or the brush over the region whose nerves we wish to stimulate. It is well to dry the skin, and, with this end in view, to sprinkle it with a little starch powder.

We should have at our command electrodes of different shapes in order to be able to work upon different parts, such as the stomach, intestine, bladder, uterus, etc. In certain cases, for acting upon the face, the hand is used as an electrode. The patient holds one hand-electrode in his hand, while the physician holds the other electrode in his left hand and with his right applies electricity to the face. To spare the physician the inconvenience of having the current pass completely through him, C. W. Müller advises that a rather large plate should be attached to the wrist of the hand which is to serve as the electrode.

Enough has now been said with regard to the various methods of electrization. In addition to these latter, the subject of general electro-therapeutics comprises the determination of the therapeutic effects produced by electricity and of the most suitable means for utilizing each of these effects.

The number of diseases in which the assistance of this powerful physical remedy has been invoked is considerable, and at present no one can entertain the idea of throwing doubt upon the great value of electro-therapeutic methods. It would also be idle to try to make a distinction among the methods of electrization from the point of view of their general efficacy and of their relative practical importance. All the methods are useful and find indications for their employment. But the reader has been able to see that our knowledge is still not far enough advanced for us to think of formulating in a precise way the mode of action of electricity upon the organism. The only certain thing seems to be that this action is very complex, even where

it is exerted upon a healthy organism. *A fortiori*, it is still more obscure and more difficult to define when we are working in a therapeutic way—*i. e.*, by applications upon parts modified by disease or upon parts whose manner of reacting deviates more or less widely from the normal.

Moreover, under a great many circumstances, we are ignorant of the real conditions under which we are introducing the electric agent. We are almost absolutely ignorant of the pathological physiology of the neuroses and of most of the diseases of the nervous or neuromotor system, diseases which are precisely the ones in which electrization scores its most incontestable successes.

It would be useless, therefore, for us to lay any stress upon the various theories upon which observers have thought to base the rational employment of electricity. Empirical results are so far the only ones that can serve us as a guide.

When we place ourselves upon the groundwork of clinical experience we are led to observe that electrization is apparently able to produce three main kinds of therapeutic effects, referable respectively to a stimulant action, a sedative action, and a trophic action.

To tell the truth, when we affirm the existence of these different modes of action we split up in a somewhat arbitrary fashion the effect of our therapeutic procedures, which is always really a complex one. Nevertheless, this classification is applicable with sufficient strictures to the results of local applications; and it has the advantage of serving to fix attention upon the principal object that is sought after by some of these applications.

The stimulant or stimulating action of the application is manifested by a return of physiological properties that have been annihilated by the disease or simply by an exaltation of these same properties when they have been lessened. It may be obtained both by local and by general applications. The local applications are the most numerous and are used particularly for stimulating the different kinds of nerves and striated and smooth muscles.

Stimulation of the sensory nerves of the skin comprises several methods. As there is no use in having a penetrating action in order to secure this stimulation, we have recourse principally to methods in which electricity acts by its high potential—*i. e.*, either to the faradic or the static method.

We already know that, in order to stimulate the sensory nerves by means of the induced current, we have to make use of a coil with

a fine and long wire, and the intermissions must be frequent. The maximum effect is obtained with the dry knob-electrode, or, better still, with the brush.

The magneto-electric apparatus may also be utilized. In this case alternating currents opposite in direction are employed.

These methods produce marked excitation of the sensory nerves, and, consequently, a return of sensibility in cases of anæsthesia. This action is not confined simply to the nerves directly affected, for it is often sufficient to apply electricity to a part only of the cutaneous surface to get, as Vulpian has shown, a return of sensibility over an extended area. A modification of the whole nervous system, therefore, seems to be produced by the reaction of this kind of electrization upon the nerve-centres.

The static method may likewise serve to stimulate the peripheral sensory nerves. The measures that are the most active in this regard are sparks and friction.

The effects obtained by these different means are complicated by reflex actions, to the consideration of which we shall have to return.

The stimulant method acquires a great importance mainly when applied to the motor nerves and the voluntary muscles. At a certain period in France, owing to the influence of the works of Duchenne, recourse was had to faradization in order to stimulate nerves and for therapeutic purposes. At present all practitioners are agreed in preferring to employ discontinuous galvanization. In order to understand better this modification that has taken place in practice, it is necessary to consider the principal conditions under which we are made to do our work. We may, therefore, discuss briefly the modifications induced in the excitability of the motor nerves and the muscles in certain pathological cases.

The questions of semeiology and diagnosis which we are going to touch upon present great importance for the therapeutist. It particularly concerns an assemblage of facts known under the name of *reaction of degeneration.*

In 1859 Baierlacher noticed that in peripheral facial paralysis the muscles lose their faradic contractility, while preserving their galvanic contractility. This interesting fact had already been observed by Hallé. More recently Erb, Leegaard, and many others have made a thorough study of it.

The reaction of degeneration, commonly represented by DR, is said to be complete when all the characters that distinguish it can be

made out; it may also be incomplete or partial. When it is complete, we are usually dealing with a motor paralysis due to alteration of the corresponding nerve. In order to get an accurate knowledge of it, we must take into consideration the facts revealed by testing the nerve, on the one hand, and the muscle, on the other.

As regards the nerve, we observe the following main facts:

For a period ranging from about twenty-four to forty-eight hours after the onset of the nervous lesion the electric excitability of the nerve is increased. Toward the third or fourth day a diminution of the faradic and galvanic excitability is observed, a diminution which is progressive. At the end of one or two weeks the electric excitability is completely lost. The duration of this state varies, being short in cases in which the affection of the nerve is a slight one, prolonged when the latter is serious, and indefinite in the incurable cases.

When the excitability reappears it shows itself first in the vicinity of the lesion, and afterward extends peripherally. The return of the electric excitability of the nerve becomes gradually more marked and pursues a more or less rapid course of development. Quite often voluntary excitability is re-established in the muscle before the nerve is capable of reacting under the influence of electricity, a fact certainly interesting from a physiological point of view.

As regards the muscles, the evolution of the phenomena is as follows:

The faradic excitability behaves in the same way as in the nerve. It hence diminishes progressively and then disappears. Later on the return of this property takes place, but more slowly than in the case of the nerve, and it remains a long time impaired.

The galvanic excitability is at first diminished; it then undergoes various qualitative modifications affecting the form and fashion of the contractions. At the time when the faradic contractility disappears the galvanic contractility rapidly increases. It sometimes becomes extreme and then is appreciable with currents which scarcely impart any deflection to the galvanometer-needle. At the same time the muscular contraction takes place in a sluggish manner, instead of being abrupt; it becomes analogous to that of smooth muscular fibres. This modification constitutes the most important phenomenon; it is made very apparent when a comparative test of the sound and the diseased side is made.

To these modifications must be added those referable to modifica-

tions of the law of contractions. We have AnCCl=CaCCl, or even AnCCl $>$ CaCCl.[1] Furthermore, the opening contractions are more readily obtained than in the normal state, and they become equal or in excess for the negative pole, which is the opposite of what is observed under physiological conditions.

Later, at the end of from three to eight weeks, according to the case, the galvanic excitability diminishes. We are then obliged to have recourse to stronger and stronger currents in order to generate a reaction.

When the cases are incurable, we continue, in spite of the progressive diminution of the galvanic contractility, to get for a long time, and sometimes for years, a reaction with the AnCCl excitation. The case is less serious when it is the CaCCl that persists.

In the cases of cure the return to normal always begins with the nerve.

The reaction of degeneration necessarily presents numerous degrees and varieties. When it is diminished it is mainly characterized by the slowness of the contraction upon galvanic stimulation, and by the predominance of the effect produced at the positive pole by closure of the circuit (AnCCl) over that produced at the negative pole (CaCCl).

The cases in which the reaction of degeneration is met with in some degree at least are numerous. We may mention traumatic paralyses or those produced by impression of the nerves, paralyses due to neuritis, the paralyses called rheumatic (particularly facial paralysis), paralyses of spinal origin (acute or chronic inflammations of the gray matter, tumors of the cord), saturnine paralysis, the paralyses due to diphtheria and to acute diseases, and syphilitic paralyses.

To sum up, we may say that the reaction of degeneration is the consequence of a secondary alteration of the muscles of central or peripheral trophic origin. It is, so to speak, the proof of the trophic degeneration of the muscles, and it is probable that all the peculiarities that it presents are the consequence of the anatomical condition of the nerves and muscles whose physiological properties have been modified.

The complete reaction indicates in general an alteration of the peripheral nerves. When the alteration producing the reaction is

[1] *More than* is represented by $>$, *less than* by $<$.

central (spinal) this reaction is commonly incomplete or partial; but there may be other causes still for the reaction being partial.

The reaction of degeneration is, then, of capital importance with respect to the anatomical diagnosis of the lesions of the nerves and muscles; but it does not by itself enable us to discover whether the origin of these lesions is central or peripheral.

The facts revealed by the study of the reaction of degeneration explain why it is preferable in a great number of pathological cases to have recourse to galvanization. As a matter of fact, galvanic currents are the only ones which, under these circumstances, can set into action the neuro-muscular excitability, or the excitability of the muscles alone. We may add that the trophic effects of galvanization are, as we shall presently see, much superior to those which the other modes of electrization are able to exert, and that hence the use of the galvanic current very probably facilitates the process of repair in the degenerated organs.

For all these reasons we should place galvanization at the head of the means used for stimulating the nerves and muscles.

The oldest of the measures used consists in the employment of Remak's labile currents. For producing these, a fairly large electrode is attached to an indifferent point and is connected with the positive pole. The negative pole is connected with a large pad electrode, or, better, with an Amussat roller, which is carried slowly back and forth over the nerves and muscles. The current should have an intensity just sufficient to excite distinct contractions. Remak also connected the movable electrode with the positive pole.

The effect produced is moderately intense in ordinary cases, but very active when the muscles are in a state of advanced degeneration.

According to Erb, the markedly stimulant action of this manipulation does not arise from the fluctuations which show themselves in the force of the current, for almost no fluctuation is seen in the indications of the galvanometer. During the movement of the electrode from place to place successively new portions of the nerves and the muscles would come under the influence of the current and would thus be stimulated.

Since the works of Chauveau and Brenner appeared preference is often given to polar stimulation. It should be employed over the muscle during the period when the excitability of the nerve is lost. The active electrode is most often connected with the negative pole;

in grave cases, however, when AnCCl becomes predominant, the positive pole is utilized.

The interruptions of the current, which are regulated by a metronome, should be carried up to a number that varies with the way in which the muscles contract; they should be less frequent the slower the contractions.

In the case of a central lesion with preservation of the excitability of the nerve we may have recourse to unipolar stimulation of the motor nerve; but it must be understood that this procedure can be applied only when the lesion is limited to a particular nervous department.

In these various cases the number of interruptions will be 60 or more a minute for sittings of from five to six minutes.

When the muscular atrophy resulting from the nervous lesion is old, the amount of stimulation produced by these various procedures is sometimes unable to give rise to a reaction. It is then possible in some cases to get muscular contractions by modifying the excitability of the muscles through the preliminary use of a continuous current. In general we use the positive pole for this purpose. After having passed a current through the parts for some minutes, a current whose intensity is very gradually increased, we make interruptions, or, still better, we slowly reverse the current, and, the negative having now become the active pole, we make our interruptions. Sometimes we use the voltaic alternating current—*i. e.*, abrupt reversals of the current—after polarization for some minutes with the positive pole. This painful method is now almost abandoned.

In diseases in which the muscles retain their faradic excitability we may make use of induced currents. We will then be careful to choose for the muscles currents of weak intensity, namely, the extra-currents or the currents provided by coils with short, coarse wire, so as to avoid too strong a stimulation, which might be followed by contracture.

For stimulating organs containing smooth muscular fibres we make use either of interrupted galvanization with infrequent intermissions, or again of extra-currents produced by coarse-wire coils and having infrequent intermissions (three to four a minute).

In recent years discharges from the tinfoil condenser have been used to produce stimulation of the muscles. Preference should be given to this procedure in all cases in which a muscular reaction can be obtained.

We may also recall to the reader's mind the use of combinations of continuous and faradic currents. The indications for them have not yet been perfectly defined.

Lastly, we may note that stimulation of the muscles may also be produced by means of static discharges. The latter sometimes constitute the only means that is active. In some very serious cases static discharges give a reaction only after a preliminary polarization of the region by means of the galvanic current.

We have already pointed out that local stimulation of the sensory nervous system by the electric agent forms one of the group of revulsive agents. It is possible, therefore, to obtain sedative effects in an indirect or reflex way by acting upon the sensory nerves of the skin with the stimulant methods that we are already acquainted with, and particularly with faradization by the electric brush. The therapeutic results of this kind of revulsion are mainly appreciable in the case of pain. In this connection it seems proper to call attention to Boudet de Paris's revulsive disk, which enables us to produce an instantaneous blister by means of the galvanic current.

Revulsive faradization has been very frequently employed against neuralgias, lead colic (Briquet), and hepatic colic. The mode of action of the faradic current in this last-named condition is quite difficult to explain, but nevertheless the author has several times had occasion to soothe the violent crises of hepatic colic by faradization of the epigastric region with moist electrodes or by antero-posterior faradization, a knob-electrode being placed in the hollow of the epigastrium and a plate-electrode being attached to the back.

The sedative method, recommended by Frommhold, consists in the use of weak faradic currents, whose intensity is steadily increased, then steadily diminished. In a great number of cases the galvanic current is used to produce a sedative effect, and is even preferred to the faradic current.

The procedures which are capable of reducing the excitability of the sensory nervous system have not yet been clearly defined. Consequently we are sometimes forced in practice to feel our way in working. In this connection we have to consider the effects attributable to the intensity of the current, to its direction, and to polar action.

It has often been said that weak currents heighten excitability, while intense currents are sedative. In reality there is no absolute rule about this. The intensity of the current ought to vary princi-

pally in accordance with the seat of the painful phenomena. In the region of the head or neck, and in spots where the current meets with very sensitive organs, it is important, as we have already said, to use weak currents, while the latter should be comparatively strong when we are acting upon the trunk or the limbs.

For a long time great importance was attached to the direction of the current. In recent years it has been determined that the influence of the direction is by no means absolute. A pain may be annihilated as well by means of a descending as of an ascending current. Hence the admonition, in case one does not succeed with one of the two, to try the current having the opposite direction.

The polar method produces the most constant results. When we wish to get a sedative action, we place the positive electrode in the vicinity of the painful spots and use a continuous current of steadily increasing intensity and duration.

Great care must be taken to establish the current slowly, and take the same precaution in bringing it back to the zero-point. It is probable that the modification produced is a consequence of the polarization of the tissues, and that the action is analogous to the phenomenon previously described under the name of electrotonus.

Remak and several practitioners since have recognized the utility of treating the pressure-points in this fashion. Under this name are denoted points which are painful to pressure (neuralgic points), or which become so under the influence of the current, when an electrode connected with the negative pole is applied for an instant at the spot where they are situated. The procedure is successful not only in neuralgias, but also sometimes when the pains are symptomatic of a central affection (ataxia, hysteria, neurasthenia). Currents that are weak or of medium strength should be employed, these being generally more useful than the intense currents. Sciatica, however, often requires the use of comparatively strong currents.

The same procedure is applicable to some of the pathological phenomena that are referable to a state of abnormal excitability of the motor sphere. The author alludes to writers' cramp, what are called essential contractures, tic douloureux, etc.

The methods of treatment that are especially applicable to motor disorders—like tonic or clonic convulsions—are not so well defined. Duchenne extolled faradization of the antagonistic muscles. We may likewise act upon the muscles by means of discontinuous galvanization.

Sometimes continuous galvanization with weak currents has been tried over the rigid muscles themselves. The results of this procedure are not so constant.

Electrization by the static method likewise affords local procedures, the result of which is manifested in sedation. Thus the local stimulation produced by sparks and by electric friction is complicated with reflex actions, the effect of which may be sedative. This is why we can succeed in assuaging by these procedures the pains of neurasthenics and hysterical subjects as well as, or sometimes even better than, by faradization.

But the procedure that is the sedative one *par excellence*, and one whose action is probably direct, consists in the use of the electric breeze. This remedy is efficacious in a large number of neuralgias. As in the aura, it has an action that is sometimes sedative, sometimes stimulating. It produces, moreover, only a very slight degree of revulsion.

We have said, in speaking of the physiological effects of electricity, that the different methods of electrization have different effects upon the vasomotor nerves, the bloodvessels, the lymphatics, the processes of molecular metamorphosis, and sometimes also upon the general nutrition; and the galvanic current in addition gives rise to phenomena of electrolysis and cataphoresis. It is to the sum total of these influences, some of which, to be sure, are still but little known, that the name of catalytic effects has been given in Germany since the time of Remak; and these effects form the distinguishing marks of what we have denoted under the name of trophic action.

It is very probable that in most cases the therapeutic effect is referable to this sort of action, which, although still obscure and not well made out, is certified to by a number of clinical observations. It is this trophic action that we seek to secure when, instead of deriving our indications from the symptoms, we go to the cause of the disease and endeavor to modify the lesion itself. Thus, in an affection of the spinal cord, for example, we may by electrization either attempt to reawaken movement and sensibility in the limbs—and this has been the object aimed at in the procedures so far studied—or we may try to modify the spinal lesion itself. It is this latter indication which is fulfilled by those measures which give rise especially to trophic actions.

The use of these measures is indicated in diseases of the nervous system with material lesions; in diseases of the nerves and muscles;

in subacute and chronic affectious of the mucous membranes and lymphatic system; and in diseases of the joints, skin, etc.

In general, we should preferably have recourse to the galvanic current, and should be obliged to do so in all cases in which it is necessary to get at the deeper organs. The faradic currents could not modify anything but the superficial lesions. The most simple procedure consists in passing a continuous current of sufficient intensity through the diseased region without altering the direction of the current.

Quite a number of observations tend to prove that from the standpoint of the atrophic effects produced the direction of the current is a matter of indifference. It has even been discovered that it is advantageous to change the direction of the current from time to time. At the same time we shall have no occasion to concern ourselves with any polar action. As it is simply a question of producing polarizatiou of a whole region, the polar action is theoretically a matter of indiffereuce, and, if in practice we sometimes observe a therapeutic action that varies according to the character of the active pole, this depends upon the fact that in reality the effects produced are always complex. As regards interruptions of the current, they may be useful in some cases; for instance, when we wish to act upon the muscles, upon the vascular nerves and vessels, etc.

Alongside of this procedure, producing what Remak has called direct catalysis, there are means of acting which give rise to trophic actions at remote points through excitation of the nerves supplying a diseased region. These latter procedures constitute indirect catalysis.

The most interesting of the means capable of producing trophic effects consists in the galvanization of the great cervical sympathetic. It is a sort of general method of treatment, with regard to whose application we must cite the names of Remak, Benedikt, Moritz Meyer, Erb, etc.

It will be noticed that when we endeavor to apply electricity to the sympathetic in the neck, we at the same time produce by diffusion of the current in the neighboring parts a stimulation of the vagus, the carotid, the nerves at the base of the skull, and probably, also, stimulation of the brain and medulla. It is really a question, therefore, of a procedure which is quite complex in its effects. Hence Erb has given it the name of galvanization applied to the neck, and de Watteville the name of subaural galvanization.

Either the method of Moritz Meyer or of Benedikt may be employed.

Moritz Meyer places a narrow electrode, connected with the negative pole, at the angle of the maxilla near the hyoid bone, and directed upward and backward toward the vertebral column. The positive pole, in the form of quite a large plate, is applied at the opposite side against the spinous processes of the fifth and sixth cervical vertebræ. The current used should be of medium intensity, and may be either continuous or interrupted. We may also reverse its direction. The application is short, lasting from one to three minutes. We may treat one side or both sides alternately.

In Benedikt's method the positive pole, in the form of a button-shaped electrode, is applied at the site of the jugular fossa, and the negative pole is applied at a point corresponding to the superior cervical ganglion. No action is exerted upon the cord in this way, and Moritz Meyer's method is for this reason preferred.

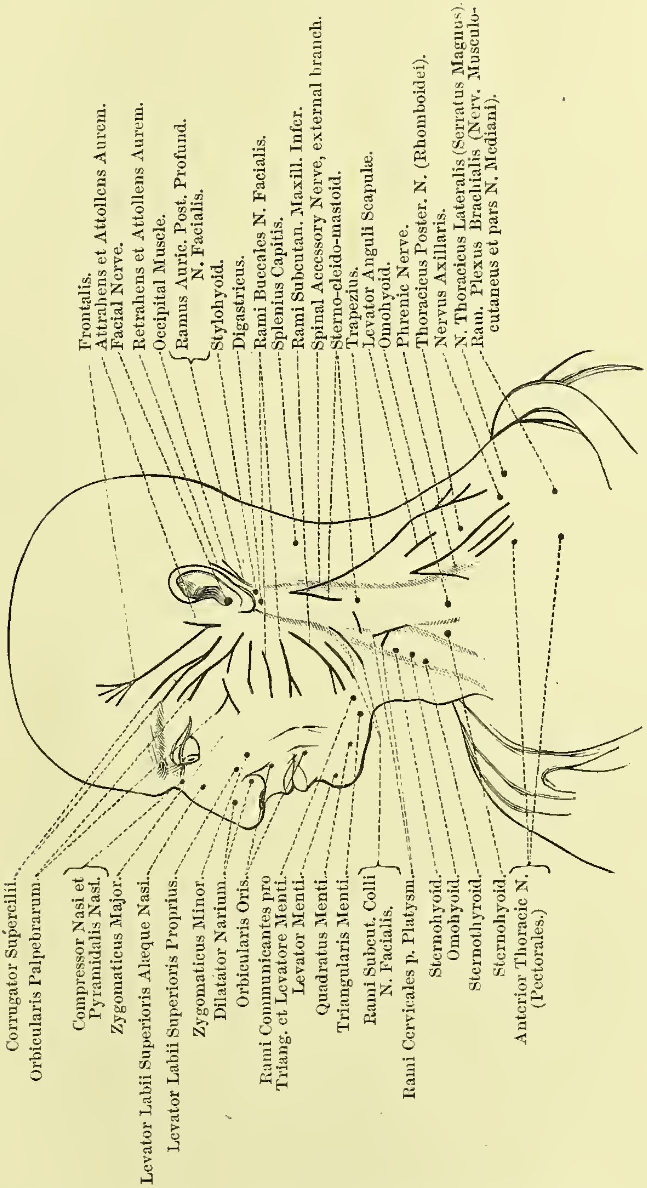
Galvanization performed in the neck has been applied in very different cases. It has been proposed in hemiplegia of central origin, neuralgias of the trigeminus, migraine, paralyses and contractures of the muscles of the face, neuro-retinitis and atrophy of the optic nerves, Basedow's disease, epilepsy, progressive muscular atrophy, chronic deforming rheumatism, scleroderma, and certain chronic skin affections, such as prurigo and eczema. The favorable results that have so far been published require confirmation.

We should likewise cite among trophic actions the effects which may be produced at a distance while we are making use of some measure capable of stimulating strongly the sensory nerves of the skin. Many of these reflex effects simply produce temporary vasomotor phenomena analogous to those which we have mentioned in speaking of revulsion and other kinds of cutaneous stimulation. They are no less important to know, since it seems as if one should refer to them, at least in part, the therapeutic results obtained in the treatment of certain congestive or inflammatory diseases of the central organs, in which we confine ourselves to stimulating certain regions of the skin, especially by means of faradization.

In the application of the principal local measures which we have just described it is necessary in order to succeed in accurately localizing the electric action, to pay attention to the precepts given by Duchenne and by von Ziemssen. A rapid sketch of the facts that are the most important to be acquainted with in practice will

therefore be given, it being presupposed that we have to work by means of faradization.

FIG. 90.



In the head the part that has been principally studied is the region of the facial nerve, a part where we have occasion most often to work.

It is useful in most cases to look, in the first place, for the trunk of the nerve. We get at it by means of a slender electrode, which we direct in front of the external auditory meatus against the posterior border of the inferior maxilla (Fig. 90). When the current is strong we get a complete and well-marked contraction of the whole facial region.

For the other branches of the nerve Erb shows three principal rami, or rather three ramifications—the upper branch, which corresponds to the muscles situated above the palpebral fissure; the middle branch, which supplies the muscles situated between the eyelids and the mouth; and the lower branch. In other details and for the muscles the schematic plate (Fig. 89) will tell more than any description.

The points of stimulation of the muscles vary much according to the subject. We should look for them with a very slender electrode, which is lightly applied, and with a current of the lowest possible intensity, for this exploration is rendered painful if we meet with branches of the trigeminus.

In the neck we find a great number of important nerves and various muscles.

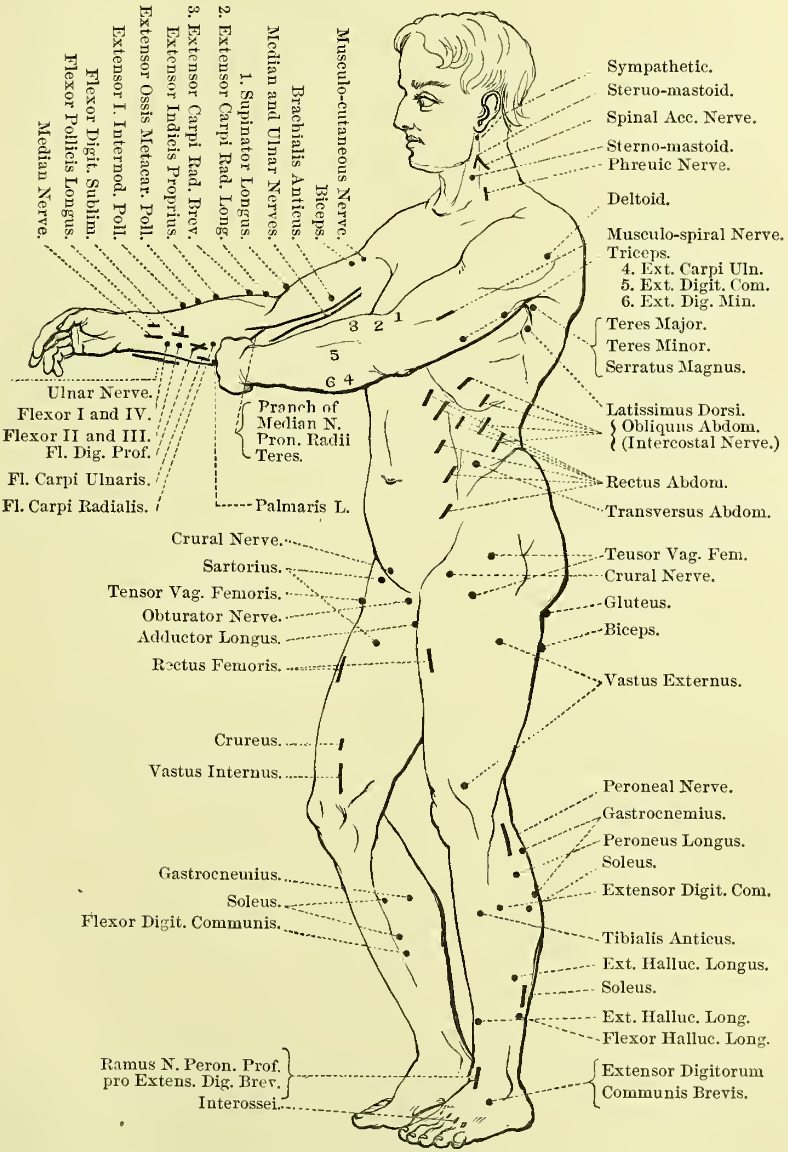
The hypoglossal nerve may be stimulated by means of a slender electrode carried deep in, above, and behind the corner of the hyoid bone. A strong current must be used. The muscles of the tongue, of the velum palati, and of the upper regions of the isthmus may be stimulated directly by means of a suitably curved electrode.

The spinal accessory is accessible in the greater part of its course; the two muscles which it innervates (sterno-cleido-mastoid and trapezius) can readily be stimulated separately. The same is true of the splenius and levator anguli scapulæ muscles. We shall less frequently have occasion to make the current act upon the hyoid muscles; it is, however, possible to get at them.

In the supra-clavicular fossa are found the brachial plexus, with all its branches, and the phrenic nerve. This latter cannot be reached separately. It must be looked for along the external border of the sterno-cleido-mastoid, a slender electrode which slides smoothly being used on account of possible contraction of the scalenus. Erb advises the use of a slender bifurcated electrode attached to the negative pole. Stimulation of this nerve produces an abrupt inspiratory movement, accompanied by rising of the epigastrium and an inspiratory laryngeal sound. Rhythmic faradization of this nerve, aided by artificial res-

piration—a method pointed out by Duchenne—has been used with success by Von Ziemssen and various practitioners since, to combat

Fig. 91.



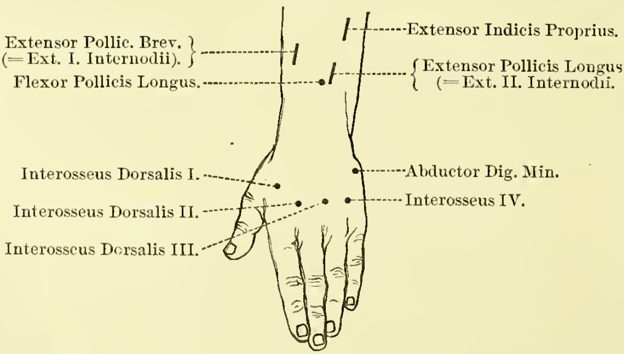
asphyxia and the accidents occurring in the administration of chloroform.

With a little care it is easy enough to get at the various branches of the brachial plexus (see the schematic plan, Fig. 89). By placing the electrode upon a circumscribed spot, about two or three centimetres above the clavicle and a little to the outer side of the posterior border of the sterno-mastoid, at the level of the transverse process of the sixth cervical vertebra, we can produce a simultaneous contraction of the deltoid, biceps, brachialis anticus, and supinator longus, and also of the subscapularis and supra-scapularis. This spot, known by the name of Erb's point (or the supra-clavicular point), has some practical importance.

In the region of the upper limb we note on the flexor aspect (Fig. 91) the ulnar and median nerves, which can be stimulated through their whole course along the internal border of the biceps muscle. The point where the ulnar nerve can be stimulated most readily is situated a little above the internal condyle; the stimulation-point of the median nerve is situated at the bend of the elbow, at the spot where the nerve lies quite horizontally upon the muscular bundle of the flexors. When these nerves are stimulated the arm ought to be kept slightly flexed and the muscles should be relaxed as completely as possible. A weak current should be used.

The musculo-cutaneous nerve is readily got at near the anterior border of the axilla, between the coraco-brachialis and the biceps.

FIG. 92.



On the forearm the ulnar and median nerves are accessible a short distance above the wrist, the ulnar nerve being very close to the tendon of the flexor carpi ulnaris, and the median nerve being situated between the tendons of the flexor carpi radialis and of the palmaris longus and brevis. (Fig. 92.)

As regards the stimulation of the muscles, the points marked upon the schematic plan give sufficient information. In stimulating the biceps we must take care to avoid the median nerve. It is difficult in the region of the forearm to stimulate separately the muscles subserving flexion; moreover, this is rarely useful. In the hand we readily get excitation of the muscles of the thenar and hypothenar eminences; it is not so easy to succeed in producing stimulation of the lumbricales.

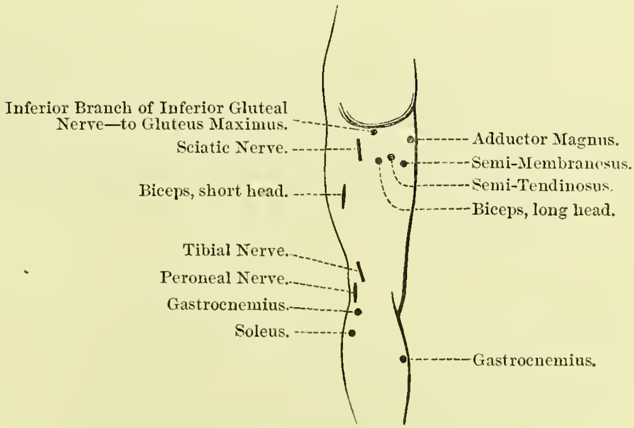
In the hollow of the axilla the nerves which can be got at separately are the axillary, the radial (musculo-spiral), and the lateral thoracic, stimulation of which causes contraction of the serratus magnus.

On the posterior aspect of the upper limb (Fig. 90) the only nerve that can be stimulated is the musculo-spiral, at the instant when it turns about the bone. The operation is quite difficult to perform. We should look for the nerve at about the middle of a line connecting the insertion of the deltoid with the external condyle, between the processes of the supinator longus and the brachialis anticus.

The muscles, with the exception of the supinator brevis, can be readily stimulated.

In the trunk stimulation can be made of the muscles only.

FIG. 93.



For producing stimulation of the nerves and muscles of the lower limbs the indications shown in Figs. 91 and 93 are sufficient.

It is necessary to have certain other facts in order to make some kinds of local stimulation. For electrization of the skull, which can

be made only with weak continuous currents, without any interruptions being employed, it is necessary to know the points which correspond to the deep parts. The region of the third frontal convolution is reached at a point a little in front of and above the ear; the region of the central convolutions extends back from this point toward the vertex.

The medulla oblongata is found between the mastoid processes and the two auriculo-mastoid fossæ; the region of the great basal ganglia corresponds to the temples, etc.

According to the position of the electrodes, a distinction is made between median galvanization, from the middle of the forehead to the middle of the occiput; right or left unilateral galvanization, from one frontal eminence to the corresponding occipital protuberance; and transverse galvanization, either frontal, temporal, or occipital, etc.

The galvanization should be made in such a way that the lesion shall be situated in the course of the shortest line connecting the two electrodes.

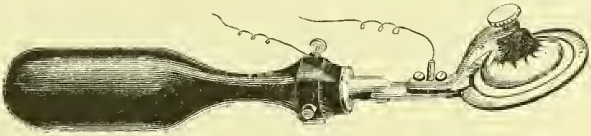
In the region of the spine we should consider the site of the cervical enlargement, extending from the third and fourth cervical to the second dorsal vertebra; and of the lumbar enlargement, extending from the tenth dorsal to the second lumbar vertebra.

Although it is better to confine the text to a summary description of the general methods of treatment by means of the electrical agent, the subject of the local applications cannot be passed by without giving some supplementary information with regard to the method of making local applications. Certain organs and certain regions of the body, as a matter of fact, require a special outfit and a special way of working, of which we have not yet had occasion to speak. The author will, however, be very brief in this part of the study, for we have already had occasion to say something upon this subject in speaking of certain kinds of medication, and we will also return to it when we shall be considering the matter of treatment.

In the first place, there is a special form of stimulator, which we owe to Boudet de Paris. In making localized applications of the galvanic current we are often troubled by the formation of derived currents. This disadvantage is particularly marked when we work upon the face, the walls of the cranium, or in the region of the neck. The concentric-pole electrode puts a stop to any danger of this kind. It consists of a metal ring (Fig. 93), which is covered with chamois-skin and screwed upon a handle with an interrupting

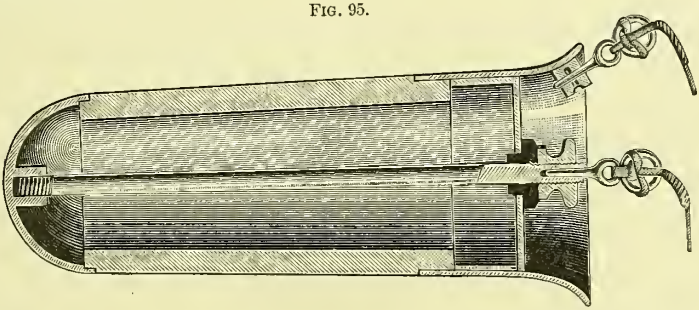
button, and which is connected with one of the poles of the battery. A bent arm, insulated from the rest of the apparatus by means of a hard-rubber plate, supports the active pole, represented by a carbon knob covered with chamois-skin. This electrode has been utilized mainly by Boudet de Paris for galvanization of the nerves and muscles of the face (paralyses of the facial, neuralgias of the trigeminus, tic douloureux).

FIG. 94.



It is not necessary to speak of the special electrodes that have been devised for acting upon the sensory organs, for these details belong to special practice. But it seems worth while to give some indications with regard to the applications that the physician is called upon to make in the internal cavities and in organs containing smooth muscular fibres.

FIG. 95.



Stimulation of the uterus is most often made by means of faradic currents. We may perform faradization in the vagina alone or an intra-uterine faradization. In both cases, especially the latter, we should take antiseptic precautions. For vaginal faradization we make use either of Tripier's vulvo-uterine electrode (Fig. 95), or of Apostoli's bipolar vaginal electrode (Fig. 97). When the latter instrument is used it is introduced gently into the vagina and applied lightly to the part to which we desire to localize the action. To employ uterine faradization we use either Tripier's single uterine

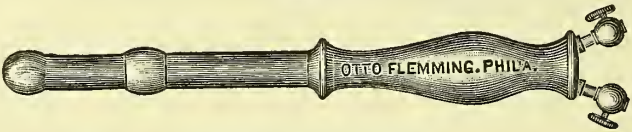
electrode (Fig. 96) or Apostoli's bipolar electrode (Fig. 97). In Tripier's method the circuit is closed by means of two large pad-

FIG. 96.

Monopolar Flexible Intra-uterine Electrode.

electrodes, terminating in a bifurcated rheophore wire, which are placed upon the abdomen just above the pubis. Apostoli's method brings both poles together within the uterus itself.

FIG. 97.



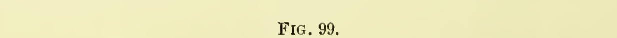
Bipolar Vaginal Electrode.

In both cases the electrode should be introduced gently and aseptically as far as the fundus of the uterine cavity, the cervical region being more sensitive to electrization. This kind of application, the duration of which should not exceed more than from three to five minutes, is useful mainly in uterine inertia and the hemorrhages which result from it.

FIG. 98.

For uterine galvanization, which may be made either by the continuous or the discontinuous method, we introduce into the vagina a sponge-electrode, such as that of Chάron (Fig. 98), the inactive pole being represented by a large plate applied over the umbilical region.

FIG. 99.

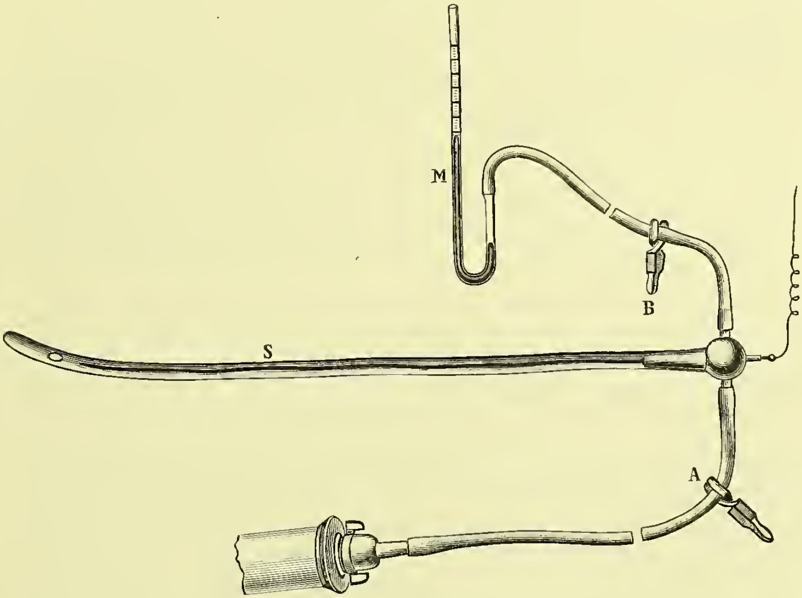


The bladder may be stimulated by analogous means. For faradization Duchenne devised a double vesical rheophore, composed of two flexible metal shanks introduced into a double-current catheter. It is simpler to use Guyon's exploratory sound (Fig. 99). This is

composed of a small metal mandrin having an olive-shaped extremity, and screwing upon the end of a metal wire. Devised for the purpose of determining the size of strictures, it represents the most practical instrument for effecting faradization either of the urethra or of the bladder.

For applying the galvanic current in the bladder, Boudet de Paris has made use of an arrangement analogous to that which we shall describe in speaking of electrization of the intestine. The hollow vesical sound (Fig. 100) encloses a single platinum wire and thus

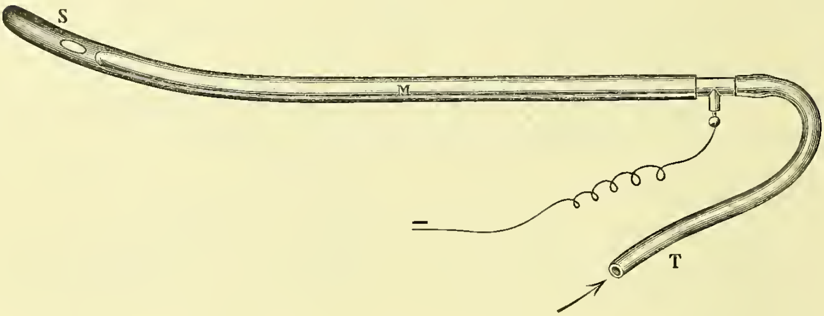
Fig. 100.



preserves all its flexibility, while at the same time it can be made as thin as may be desired. To this sound is fitted a short, hollow, branched mandrin; connected with one of the branches is a tube which enables us to empty the bladder and to replace the urine by a certain quantity of water. As it is of importance to estimate the intensity of the vesical reaction, the other branch of the mandrin terminates in a water or mercury manometer. We may thus, in imitation of the method devised by Mallez for studying the energy of the vesical contraction, observe and measure the smallest contraction of the bladder.

Boudet de Paris's ingenious method for obtaining energetic contractions of the mass of intestines is also devised from the preceding method. To avoid the production of eschars of the mucous membrane, to which the use of the strong currents that are necessary in some cases might give rise, Boudet de Paris makes, by means of a special arrangement, a sort of liquid electrode of very large surface. A large rubber sound (Fig. 101) is introduced into the rectum. It is provided with a tubular metal mandrin whose end does not reach quite up to the eye in the side of the sound. This mandrin is attached

FIG. 101.



by a conducting-wire to one of the poles of the battery. By means of a rubber tube it is connected with the canula of an irrigator or ot a syringe, and in this way the rectum can be filled with water containing a small amount of salt. The other pole of the battery terminates in a large plate, which is placed either in the dorsal region or upon the abdomen. The most effective method consists in sending a current increasing steadily in strength up to 10 milliampères, the positive pole corresponding to the rectal electrode; then at the end of two or three minutes reversing the direction of the current. Sometimes strong peristaltic contractions are generated. They may be produced by means of interruptions made at very long intervals.

In quite a large number of cases the object of the electric treatment is not to act upon a limited portion of the body, but to produce a modification of general innervation or nutrition. We then have recourse to methods capable of producing an impression upon the whole organism and giving rise to complex effects. These are the various measures for producing general electrization.

The electrostatic bath, although the gentlest and least stimulating of these measures, is endowed with an undeniable therapeutic action,

which makes it valuable in quite a large number of cases. It has been successfully employed in most of the neuroses by Mund, Stein, Benedikt, Charcot, etc. In neurasthenia Stein recommends the positive air-bath. The same kind of bath has been employed by Féré in electric neuroses—*i. e.*, in subjects giving sparks at the ends of the fingers, or experiencing a state of fatigue attended with vasomotor disorders, and attributable to an excessive loss of electricity. The static bath has also been used in anæmia and in certain forms of dyspepsia referred, rightly or wrongly, to the presence of a neuropathic condition.

The other methods of producing general electrization which we have left to describe are general faradization and galvanization, central galvanization, and the electric baths.

For the *general faradization* of Beard and Rockwell the patient is placed on a moist and warm copper platform, which is connected with the negative pole, or, better still, is seated upon a large wet sponge attached to the same pole. The physician applies the electricity either with his hand or with a sponge-electrode. The active electrode is carried first over the forehead, head, and nape of the neck; then with stronger currents over the vertebral column, the neck in the region of the sympathetic, the vagus, the phrenic nerve, etc. Afterward we pass to the region of the epigastrium, and stop there for a certain time. The sitting is ended by energetic stimulation of the muscles of the limbs.

This procedure causes quite an intense general excitation, which is capable of giving rise to malaise, tremor, and sometimes even syncope. At the end of some days it produces fatigue, muscular pain, cephalalgia, and insomnia. But after a certain number of sittings all these phenomena disappear, sleep returns, the appetite is increased, the circulation goes on with renewed activity, the volume of the muscles increases, the pains disappear, and a feeling of well-being succeeds the malaise of the first days of the application. In reality, therefore, the effect obtained is a sedative and restorative action. Hence, the procedure has been recommended in cases of general neurasthenia and in the state of exhaustion following a long and difficult convalescence. It has been employed successfully by Maienfisch, by Moebius, and by quite a large number of other physicians.

General galvanization was conducted by Väter von Arteus in the following manner: The patient is connected with a large fixed nega-

tive electrode, as in general faradization, and the active positive electrode is represented by a large sponge having an area of 30 square centimetres. This electrode, while being constantly moved about, ought never to break contact with the integument. It is allowed to rest upon certain spots. Väter makes two circuits above, two circuits below, a cephalic circuit, and a spinal circuit. In making the upper circuit the sponge is placed between the fifth and seventh cervical vertebræ, and remains fixed there. The operator adjusts the current, which should be weak, and then passes the electrode slowly over the lateral portions of the neck as far as the auriculo-maxillary fossa; then, following the anterior border of the sterno-cleido-mastoid, descends upon the sternum, and, passing transversely outward, returns over the brachial plexus, and from there over the pectoral muscles and upon the arm, following the bicipital groove. He next passes along upon the median nerve, the motor points of the ulnar nerve, then upon the flexor muscles of the forearm down to the lower border of the ulna, over upon the hand, then upon the radial side of the forearm upon the motor point of the musculo-spiral nerve, and upon the triceps and deltoid, finally returning to the starting-point in the supra-clavicular fossa. The other arm is treated in the same way.

After making the second upper circuit, the operator passes the electrode several times from above downward, and from below upward, along the vertebral column.

The cephalic circuit consists in placing the electrode upon the nape of the neck, and then upon the mastoid process of one side. From this point the operator makes the circuit of the ear and passes over upon the temporal region and the forehead, then upon the temporal region of the opposite side, and so on back again to the starting-point.

The two lower circuits begin in the lumbar region; from this point the operator directs his course toward the lateral portions of the abdomen, and from here again proceeds so as to stimulate the lower limbs, beginning with the crural nerve, and working as in the case of the upper limbs.

Each superior and inferior circuit lasts two or three minutes; the cephalic circuit half a minute or more; the spinal circuit half a minute. The current should be weak, particularly when passing in the vicinity of the nerve-centres, the plexuses, and the great nerve-trunks.

The *central galvanization* of Beard, or paracentral galvanization of Väter, consists in applying a large fixed negative electrode to the abdomen, and in passing a positive sponge-electrode, having an area of 30 square centimetres, over the parts corresponding to the nerve-centres. The operator begins by passing over the forehead from one side to the other, then over Beard's cranial centre—*i. e.*, the vertex of the skull midway between the ears, the hair being well wet when this is done. From this point he goes toward the occiput, then toward the auriculo-maxillary fossa, from which region he descends upon the lateral portions of the neck as far as the fifth or seventh cervical vertebra, in such a way as to cover the cilio-spinal centre, and finishes the sitting by making friction along the vertebral column. The current should be weak and the duration of the whole operation from ten to fifteen minutes.

The effects of general galvanization are sensibly the same as those of general faradization.

Central galvanization is said to produce chiefly improvement in sleeping, increase of the appetite and the muscular force, reawakening of intelligence, and the disappearance of fatigue. An increase in the body-weight is not observed after this treatment, this being produced only by general faradization.

The indications for the general measures are numerous. They comprise, apart from the neuroses, those diseases that are associated with disorders of nutrition and involve, from their long duration, a more or less intense wasting of the organism.

It is conceded that in cases in which it is desired to act specially upon the central nervous system preference should be given to general galvanization; and that general faradization has a more marked action upon the skin and the muscular masses, and that it is particularly adapted for producing a general tonic action.

As to central galvanization, Beard used it especially in neurasthenic states associated with but slight impairment of the general nutrition and of muscular power. In these cases he gives the preference to general faradization.

General electrization is also obtained by means of electric baths, the use of which is comparatively recent.

According to Bouillon-Lagrange, the idea is due to Moretin (1864). In 1866 Séré presented to the Academy of Sciences a model of an electric bath of a cement bath-tub, at the ends of which were arranged two carbon plates which conducted the current. Several trials

of these baths were made at this time in the Hospital Saint-Louis. Since then the electric bath has been made the subject of researches by Paul (1871 and 1880), and more recently has been studied in a scientific manner by Stein, Eulenberg, Lehr, etc.

The electric bath has several forms. The local bath has been given up, and, hence, what is now meant by the term is a bath in which the patient's entire body is immersed in the water. This bath can be given with the galvanic current or with the induced current. We have, therefore, a faradic bath and a galvanic bath, and either one may be unipolar or bipolar. Finally, Stein has devised a particular form of administration to which he gives the name of the electric douche.

It is interesting to consider what are the physical conditions that are created by the immersion of the body in water.

The moment the patient is immersed in the bath the resistance of the external circuit diminishes, so that the intensity of the current increases.

Thus, for a certain number of cells, we have:

$$I = \frac{E}{r + R},$$

r being, as always, the internal resistance of the battery and R the external resistance represented by the water of the bath. This resistance, R, becomes much smaller when the patient is in the water. We get, other things being equal:

$$I' = \frac{E}{r + R - R'},$$

R′ representing the quantity by which the resistance of the circuit is diminished.

Lehr has proved that the diminution of the resistance does not spring from the increase in the sectional area of the aqueous conductor produced by the immersion. In fact, this diminution is maintained when the level of the water is reduced to the former height. This experiment in itself alone would tend to prove that the body is traversed by the current.

Various other considerations of a physical nature and several experiments made by Weisflog with the induced current and by Stein with the galvanic current have rendered it possible to establish the fact that the body when immersed in the water forms an integral part of the external circuit, and is not, as some authors have believed,

in parallel circuit with the water. Chauveau's researches, too, upon unipolar stimulation, made some time ago, have left no doubt whatever upon this point.

It results from this that the monopolar bath has the disadvantage of producing a current of too great a density over the part which is situated outside of the water and which forms the connecting-link in the circuit.

In general, preference is given to the bipolar bath, and a greater number of plates than two are used. By thus increasing the sectional area of the conductor, we facilitate the passage of the current through both the body and the water. The plates should be of equal area. Otherwise the current would become too dense at the site of the smallest electrode, and the patient would experience a sense of pricking if the galvanic current were employed, or a muscular contraction if it were the faradic current. Stein has finally fixed upon the following arrangement: The positive pole is connected with a hollowed-out plate placed near the head, and the negative pole corresponds to two plates, one situated at the feet, the other between the legs. The patient's hands ought to be applied along the thighs.

The bipolar bath has been charged with being the seat of polarization phenomena, partly at the surface of contact between the electrodes and the water and partly at that between the water and the surface of the body. These phenomena would give rise to inverse currents, opposing the principal current. When the electrodes are large the density of the current is low and the polarization phenomena are reduced to a minimum. It is precisely the opposite in the unipolar bath; the current becomes very dense at certain points at which the polarization reaches its maximum. There results from this a very disagreeable sensation in the wet hands, which serve to form the connecting link in the circuit outside of the water; and this is particularly the case when the positive bath is employed. We must not try to make the water a better conductor by adding salts or acids to it, for we shall thus oppose the very end which we are seeking to attain; that is, we shall prevent the passage of the current through the body.

Owing to the fact of immersion, the resistance of the epidermis is considerably diminished, and the faradic current can, under these conditions, act more deeply than by any other method.

Stein's electric douche is administered in the following manner:

A large receiver filled with a saline solution and placed some dis-

tance above the patient communicates by a pipe with an apparatus, by means of which either a jet-bath or a shower-bath can be given. To this apparatus is soldered a terminal to which can be attached the positive or negative rheophore of the battery or of the induction-apparatus. The patient, seated in the bath, is in connection with the pole of opposite character.

When the stopcock of the hydrotherapeutic apparatus is opened, the water emerging from the ball of the shower or from the orifice of the jet-tube, and striking the patient's skin, closes the circuit and produces marked excitation similar to that which is caused by the electric aura. The mobility of the douche-pipe enables us to localize the stimulant action, which is, moreover, reinforced by that of the water.

Stein's method presents a further interesting peculiarity. This consists in the production of a sort of electric massage by means of a roller electrode, at the moment when the patient is about to leave the bath. This application is made while he remains standing in the water, which thus serves as an electrode.

For the faradic bath, which is the kind most often made use of, a coil with very coarse wire is employed, which gives quantity, and which is run by two bichromate cells or by two accumulators. The galvanic bath requires the use of an intensity-battery, for instance, of a battery of 30 to 40 bisulphate cells, as the resistance to be overcome is quite considerable.

The electric bath produces modifications of the pulse, respiration, temperature, and farado-cutaneous sensibility ; it furthermore effects the excitation of the motor nerves and muscles and influences the general nutrition.

According to Eulenberg, the frequency of the pulse diminishes by from 8 to 12 pulsations in the faradic bath, and from 10 to 30 in the galvanic bath. Lehr has seen palpitation and arhythmia occur with currents of great intensity.

The frequency of respiration is likewise diminished (Eulenberg), and this phenomenon is more marked in the bipolar than in the unipolar bath (Lehr).

The body-temperature is reduced in all cases, whether the bath be faradic or galvanic (Lehr).

The excretion of urea is increased distinctly by the galvanic or bipolar faradic bath, very slightly by the negative unipolar bath.

The action of the electric baths is, on the whole, according to the

results obtained by Eulenberg and Lehr, very similar to that of the stimulant thermal or chemical baths. They may, at the end of some time, result in producing a general sedative effect.

These baths have been employed empirically in all cases in which the usefulness of general electricity has been recognized, *i.e.*, in neuroses (hysteria, neurasthenia, hypochondriasis, Basedow's disease, etc.) and in certain chronic affections (arthritis deformans, chronic gout, obstinate dyspepsia, etc.). The indications for them are sensibly the same as those for general electrization. It is, indeed, nothing else but one form of general electrization, and often the only one whose use is tolerated when the patient is of the female sex.

The effects produced are likewise those of general electrization: improvement in sleeping, rapid and permanent return of the appetite, especially in cases of dyspepsia; regulation of the intestinal functions, heightening of the general nutrition, and, as a consequence, increase in the body-weight, etc.

According to Lehr, the duration of the electric bath should be short—from ten to fifteen minutes—when it is desired to produce a sedative and tonic action. It may be carried up to thirty minutes in cases in which we wish to get a diminution of sensory and motor excitability (tremors, spasms, contractures, etc.). The temperature of the water is 32° to 35° C.; it should be higher for rheumatic patients than for others.

The passage of a galvanic current through a saline compound tends, is known to decompose it; at the same time, when two solutions are separated by a membrane, a movement of translation is set up, either in the same direction as the current, or in the opposite direction, according to the substances upon which we are acting. These phenomena with which we have had to do when speaking of electrolysis and of cataphoresis have been utilized in therapeutics. In particular it has been sought to facilitate, by means of the galvanic current, the passage of certain medicines through the uninjured skin.

The first experiments, made by Munk, B. W. Richardson, and Onimus, had given rise to the hope that we had become possessed of a new and efficient method of introducing medicines into the organism, when Lauret submitted the question to the test of accurate experimentation.

Lauret made use of a high and narrow block-tin bucket, having soldered to its walls a metal terminal for the reception of one of the rheophores of a battery.

The patient immersed his forearm in this bucket, which was filled with a medicinal solution, and the galvanic circuit was closed by means of a large electrode applied to the arm and connected with the other rheophore of the battery. The results of this conscientious observation, which were announced in 1885, are very interesting. Lauret showed that the number of medicinal substances whose absorption through the skin can be facilitated by the current is very limited; that these substances are not absorbed undecomposed; that some of their elements, set free by the electrolytic action, are the only ones capable of being absorbed; that, for instance, the use of solutions of the iodides, bromides, and sulphides may be followed by absorption of the iodine, bromine, or sulphur; and, lastly, that the amounts absorbed are too insignificant to make it possible for this way of introducing medicines to be of any great efficacy. He observed, however, that the application of this measure is sometimes in practice followed by therapeutic results.

Since that time experiments of this sort have not been greatly multiplied; still we may quote the method which Edison proposes for dissolving tophi in gout. This great physicist immerses the patient's hands or feet in two vessels, one of which contains a solution of a lithium salt (lithium chloride), the other a solution of salt (sodium chloride); the first vessel is connected with the positive pole of the battery, the second with the negative pole. Examination of the urine has shown him that under these conditions a notable proportion of lithium passes into the general circulation. We may also add that Imbert de la Fouche has proposed to treat rheumatism and gout by cataphoresis by using a procedure which had been already mentioned by F. Peterson, and which consists in applying large sponge-electrodes, one of which, connected with the positive pole, is impregnated with a medicinal solution. The operator in this case has to make use of high intensities and increase gradually until he reaches 80 to 100 milliampères.

These various kinds of partial applications certainly cause but a small proportion of the active substances to penetrate into the body. This is not the case apparently when we act upon the whole cutaneous surface, as Gaertner and Ehrmann propose doing.

Gaertner has had constructed a bathtub divided into two compartments by means of a diaphragm. The latter may be fitted almost hermetically to the human body. The walls and bottom of the tub are lined with electrodes formed of plates of copper and zinc covered

with a perforated strip of wood. One of these compartments is connected with the positive, the other with the negative pole of the battery, and they communicate with each other by means of the patient's body, the diaphragm being constructed of some insulating substance, and the water passing from one compartment to the other only by fissures that are almost capillary in size. Under these conditions the greatest part of the current, the intensity of which is measured by the galvanometer, passes through the body, and, furthermore, the density of the current is equal in all the points submerged. By means of this contrivance the authors have administered baths of corrosive sublimate. They placed four grammes of sublimate in the lower compartment, which was connected with the positive pole, and used an intensity of 100 milliampères. In all their experiments a very notable elimination of mercury by the urine took place after the bath.

The time has not yet come for pronouncing upon the value of these various procedures. The one last described seems to be capable of giving more marked results than do the local applications, but no certain proof of this has been, as yet, afforded.

G. Gautier has thought of another method which he proposes to call the electro-chemical method. Instead of utilizing the properties of the current in order to render endosmosis more energetic, he has conceived the idea of making use on the spot of the products of the electro-chemical decomposition of the medicines. The following is an example of one of the operations that he has performed. He withdrew 150 grammes of pus from a purulent sac by puncture, and injected an equal amount of a solution of iodine or an iodide; then, leaving the positive pole of the battery in the sac, he passed a current through the latter. The solution used had the following formula:

Water	20
Potassium iodide	1
Glycerin	3

Iodine, in the nascent state, is produced capable of exerting a microbicidal and cicatrizing action upon the walls of the cavity.

G. Gautier appears to have treated in this way with success lupus, actinomycosis of the face, fungous arthritis, tuberculous abscesses, sycosis, etc.

There is now one more method to be studied.

This method is derived from the chemical galvano-cautery or

voltaic chemico-cautery of Tripier, which has been used for quite a long time.

It will be recollected that the galvanic current produces in the neighborhood of the electrodes chemical phenomena the intensity of which is proportioned to the density of the current. When the electrodes are metallic a current that has comparatively little density is sufficient to produce eschars, which are dry at the positive pole and moist at the negative pole. If, for example, we plunge two gold needles into the tissues of an animal, some centimetres apart, and connect each needle with the poles of a battery, we shall, if we pass through them a current of 15 to 20 milliampères, see the skin at first grow pale at the point where each needle is inserted. The effect produced is more pronounced at the negative than at the positive pole. If we continue to pass the current through the parts for some minutes, a small circular eschar will be formed about each needle. The eschar produced by the positive needle is brown, dry, and takes a long time before it is detached; the eschar formed at the negative needle is white, soft, and followed by cicatrization which progresses twice as fast as in the other case. The former is identical with the results of the cauterization of the integument by acids, the latter with those of cauterization by caustic alkalies.

Suppose now that we act upon blood, or, more simply, upon a solution of albumin (white of egg), and plunge our needles into one or the other of these. At the end of some minutes we notice about the needle connected with the negative pole a sort of frothy mucus resulting from the action of the alkalies and the evolution of gases; about the positive needle we see a sort of solid coagulum without froth, which assumes an ochre hue when the needle is made of iron.

Such are the chemical effects which it is our object to produce when we make use of medical electrolysis—*i. e.*, of chemical galvanocautery (voltaic chemico-cautery of Tripier). The latter may be defined as the sum total of the operations made by means of the galvanic current and with electrodes which are very good conductors, and which are placed directly in contact with the tissues with the object either of producing a partial or complete destruction of the latter, or of causing a chemical modification in the tissues and liquids in contact with the electrodes.

In some of these operations there is reason for taking into account, from a therapeutic standpoint, the modifications which are produced in a more or less extensive zone in the neighborhood of the points

directly touched, and which are manifested in the tendency to disappear displayed by certain lesions. Tripier has given to this therapeutic action, representing the remote result of electrolysis, the name of *electro-resolution.* This term does not comprise all the results that may follow electrolysis. For example, in the treatment of aneurisms, electric applications give rise to quite complex effects which cannot be placed in the category of a resolvent action.

In a certain number of cases the destruction of the tissues should be complete. Such should be the result of electrolysis when applied to the treatment of strictures of the urethra or of the cervix uteri, fistulæ, malignant tumors, etc.

Under these circumstances we seek only to establish rapidly a channel or way of communication between the exterior of the body and certain deeply-placed swellings—circumuterine or perinephritic abscesses, hydatid cysts, etc. This sort of operation has received from Tripier the name of *tubular cauterization.*

The outfit necessary for performing these various operations will vary according to the object to be attained. Any medical battery may serve the purpose; but it is necessary to take into account the resistance to be overcome, and to select the cells used, and the number of the latter accordingly. The ordinary methods of operating do not require the use of great intensities. The latter are brought to bear only in the operations devised by Apostoli for the treatment of certain diseases of women. In these cases it would be necessary for the operator to have at his command quite a powerful battery, a galvanometer capable of indicating a considerable intensity (up to 300 milliampères), and a current-selector that will enable him to take the cells one by one, or, in default of this, a rheostat.

The special form of outfit is represented in the main by different kinds of electrodes.

In a large number of cases one of the poles is inactive. As it is often necessary to use an intense current, the attempt must be made to prevent the formation of eschars near the indifferent electrode by giving the latter a large surface—*i. e.*, by rendering the current less dense at that point. With this object in view, Boudet de Paris has proposed placing a large plate, 20 centimetres square, over each thigh, and often, too, a third plate over the kidneys. These three plates connected together represent a total surface of about 12 square decimetres, which enables us to get great intensity with a comparatively small number of cells.

Apostoli has for the same purpose devised a special electrode, which is at present used in gynecological operations that require the employment of great intensities. This electrode is made of clay, and it is a good thing for the physician to be able to make it himself. The clay ought to be as plastic as possible and free from sand. It should be very soft, so as to be able to stick to the skin and to be moulded accurately to the parts to which it is applied. This region is generally the abdomen.

To make this electrode it is enough to have a rectangular wooden or iron frame, 30 centimetres long by 18 broad and $1\frac{1}{2}$ high. To this is applied a piece of wide-meshed tarlatan, which has been previously wet, and thus a space is formed in which the clay is placed in the form of a very wet cake. The projecting edges of the tarlatan are pressed down and the clay cake is lifted from its mould. To its surface is applied a large metal electrode, which is pushed into the clay a moderate distance.

Fig. 102.

Fig. 103.

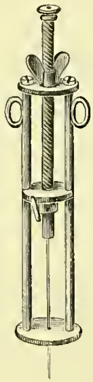


Fig. 104.

Electrolytic Needles.

The active electrodes are in most cases needles of gold or steel. Their length is necessarily very variable; their diameter ranges between the extreme limits of a third of a millimetre and a millimetre. (Fig. 102.)

When the electrolysis must be made deep down (in the treatment of aneurisms, for example), we must be careful to cover the needles, except at their points, with a thick coating of insulating varnish for a length of several millimetres. This varnish is for the purpose of protecting the skin and the tissues in contact with the needle from the chemical action which, without this precaution, would take place along the whole length of the needle, and would cause the formation of eschars, which might often be very dangerous. Buij has proposed to enamel with glass the protected portion of the needles.

To insert and to draw out the needles we use the instruments which Dujardin-Beaumetz has had constructed for the electrolytic treatment of aneurisms. By means of the *needle-plunger* (Fig. 102) the needle can be thrust rapidly and by a single motion to the desired depth. The *needle-retractor* (Fig. 103), constructed on the model of the perfected corkscrew, enables the operator to avoid all the accidents to which he had been exposed after positive cauterizations when he used the forceps. The instrument takes its bearing from the skin about the needle, and the latter, being gripped in a nut provided with a screw-thread, is withdrawn without effort or without oscillations, and follows the same direction that it had when entering the tumors.

The needles should be connected with the battery by means of very light and slender rheophore-wires, which end in a small serre-fine that is fastened upon the free end of the needle.

When it is simply a question of destroying a superficial tumor, a nævus, for instance, or of performing epilation, the destruction of chalazia, etc., the needle is simply placed in a needle-holder, and can thus be manipulated with precision (Fig. 104).

In the region of the face the preceding arrangement must be modified, on account of the deviation effects that may be produced.

Fig. 105.

Experiments by Boudet de Paris have shown to his satisfaction that the dangerous zone has for its lower limit a circular line passing along the level of the mastoid processes and the alæ of the nose. The cheek, nose, eye, temple, and forehead are comprised within

this zone. For tumors situated in this region, all accidents may be avoided by making use of the concentric electrode of Boudet de Paris, with which we have already become acquainted. In the present instance the carbon plug is replaced by a needle (Fig. 105).

We may operate in this way upon nævi, sebaceous cysts, and chalazia. For erectile tumors we may make use of a plate, pierced in the centre with quite a large orifice, lodging several needles.

Strictures of the urethra, which have been successfully treated by electrolysis (Tripier, Mallez, Jardin, Fort), require the use of a special urethrotome (Jardin's urethrotome). It is an ordinary urethrotome in which the blunt knife is connected with the negative pole of a battery.

The treatment of hypertrophy of the tonsils is performed by means of a special electrode, which we also owe to Boudet de Paris. The gland is transfixed with a positive needle, and is surrounded by a negative metal ring.

Tubular cauterization is performed with a trocar of varying length and diameter. The instrument may be of steel, gold, or platinum. In spite of the disadvantages that steel has when we make a positive cauterization (which is not the one ordinarily used), the steel trocar has the advantage of being sharper and of making a better puncture.

Numerous electrodes are used in gynecological practice.

The electrode to be preferred is the platinum hysterometer of Apostoli. (Fig. 106.) It ends at one extremity in a rounded and polished surface, like an ordinary hysterometer, and at the other

FIG. 106.

Apostoli's Monopolar Intra-uterine Electrode.

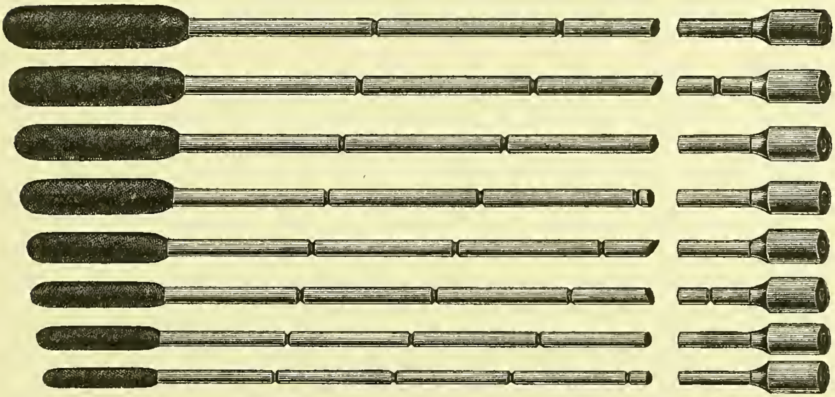
extremity in a trocar, so that the same instrument may serve for surface cauterization and tubular cauterization. A part of its shank is enclosed in a celluloid insulator.

In a certain number of cases preference is given to the carbon electrodes of Apostoli or of Brivois, which are used to perform intra-uterine cauterizations. The ordinary carbon electrode measures 2 centimetres in length, and is of variable thickness in accordance with the varying dimensions of the uterine cavity. It is mounted

on a long copper handle, covered with a caoutchouc or celluloid insulator. Divisions every 2 centimetres, representing the length of the carbon attachment, are marked on the handle by notches visible to the eye and appreciable to the touch, so that when withdrawing this electrode from the fundus of the uterine cavity in order to carry it to another part that has to be cauterized we can estimate the amount of displacement. The length of the carbon may be increased according to the indications to be fulfilled (Fig. 107).

The number of affections treated by means of the chemical galvano-cautery is considerable. To those which have already been mentioned may be added goitre, stricture of the lachrymal pas-

Fig. 107.



sages, abscesses occurring in ganglions and in the labia majora and about the margin of the anus, various kinds of cysts, both cutaneous and deep, lipomata, fibrous tumors, etc.

For details concerning these operations the reader is referred to special treatises.

The author desires, before closing, to speak of galvano-thermics, confining himself to stating its principles and to showing the ordinary outfit for it.

The name of electric cautery or of galvano-cautery is given to an instrument in which calorific energy is derived from the galvanic current. We owe its introduction into surgery to J. Marshall, Nélaton, Mitteldorf, and the younger Amussat.

At the time when the voltaic thermo-cautery was devised it formed a considerable step in advance, although the importance of the latter

has been diminished by the discovery of the Paquelin cautery. But this latter has not completely dethroned it, for the electric cautery lends itself to special uses and possesses peculiar properties.

To apply the voltaic thermo-cautery it is necessary to use as one source of electricity the quantity batteries which have been previously described. At present a current furnished by accumulators is generally made use of.

As it is necessary that the temperature of the active part of the cautery should admit of being varied at will, the intensity of the current should be regulated by means of a rheostat. The total resistance being here very low, small variations in the resistance introduced artificially into the circuit suffice to produce a very appreciable variation of the intensity of the current. Hence, we may use a very simple rheostat, such as that of the Trouvé polyscope, supplied with German-silver spiral wire, the length of which can be varied. We may also use as a rheostat a test-tube, containing mercury. The current, for example, may enter in the lower part of the mercury column and make its exit through an iron shank which can be slid into the stopper closing the tube.

The ordinary form of galvano-cautery comprises an insulating handle (Fig. 108); a conducting portion, formed of shanks of gilt brass,

FIG. 108.

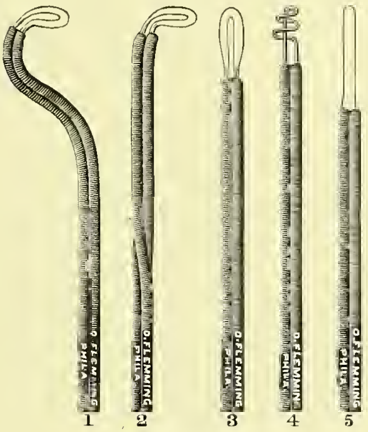
Universal Cautery Handle.

having a large sectional area and consequently a resistance which can be ignored, and the cautery-point proper. The shanks traverse the insulating handle. They may consist of a single piece or of several screwed or attached to one another. In the interior of the handle one of the shanks is formed of two portions, which are separated from each other when the current is not passing. Contact is established by means of a button at the moment when the instrument is set in action. There is a bolt which can keep the circuit closed when the operation is to last some time.

The cautery point proper may have an infinity of forms. In all cases it is made of platinum. It is sometimes a flattened blade (galvanic knife), sometimes a platinum wire of small sectional area, to

which may be given any shape that may be wished. This may be wound in the form of a loop when it is intended to divide the pedicle of certain tumors; it is given the shape of a more or less blunt point when it has to penetrate in a narrow passage, etc. (Fig. 109).

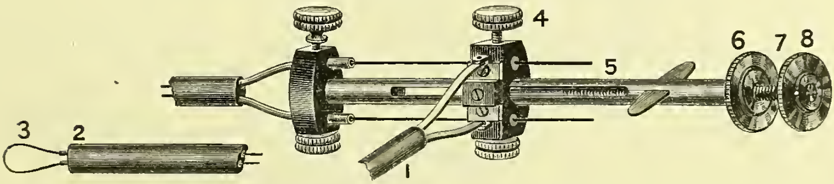
Fig. 109.



Cautery Points.

Sometimes it is necessary to vary the length of the loop during the operation. This loop then forms part of a long platinum wire, whose ends are coiled about a windlass, or, better still, are attached to movable pieces, which the operator can readily slide from one place to another and stop when he wishes (Fig. 110).

Fig. 110.



Most authors advise keeping the temperature of the cautery-point at a dull-red heat during the course of the operation. Onimus has called attention to the fact that when the temperature is too high the point cuts like a bistoury, a circumstance which prevents the latter from acting with the slowness necessary to secure coagulation of the blood. Hence, for operations which are performed upon pathological tissues of quite large size, the necessity of being able to vary the

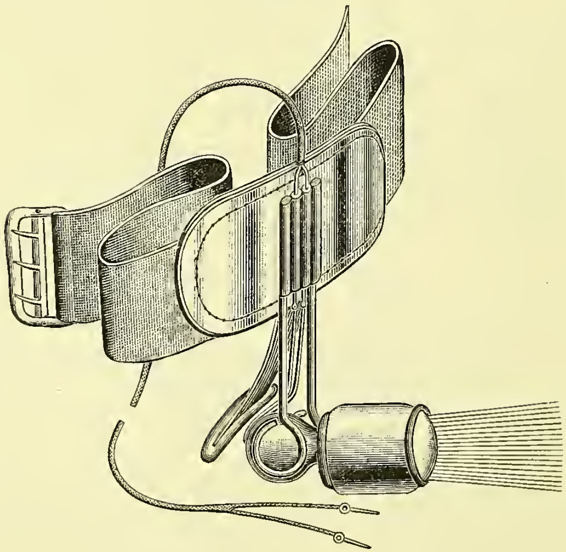
intensity of the current by means of the rheostat during the course of the operation itself should be remembered. The operator will do well, therefore, in order to guide himself, to try the cautery-point first upon a piece of meat having the thickness of the tissues that he has to go through, and to observe the various resistances that are to be got by means of the rheostat when the section is made under good conditions.

FIG. 111.

Kyle's Electric Lamp.

Galvano-thermy presents weighty advantages. It enables us to introduce and to withdraw the cautery-point when cold, and either to keep the point at the same temperature during the whole opera-

FIG. 112.



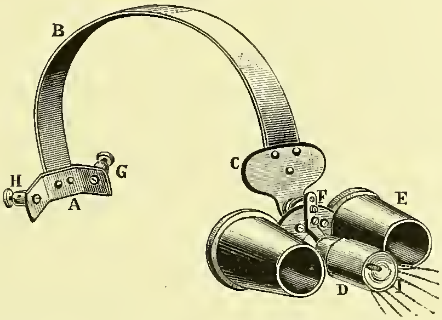
tion, or, on the other hand, to vary the temperature at will. It brings into play an instrument to which any shape can be given, and which is hence adapted to all kinds of uses. Finally, the galvano-cautery point loses but little heat by radiation, and when it has the

form of a loop it possesses at once the advantages of a cautery iron and of a linear écraseur.

The applications of the galvano-cautery in cavities necessitate the use of illuminating apparatus, in which case the light may be derived from the luminous effects of electricity.

Any practitioner having in his office the necessary outfit for voltaic galvano-cautery may at the same time run the illuminating apparatus of which he may stand in need.

Fig. 113.



It is only necessary to speak of the various models of incandescent lamps. Here is one (Fig. 111) fitted to a laryngoscope. Another forms the principal part of an instrument designed under the name of photophore by Hélot and Trouvé; this apparatus may be attached to the forehead of the operator like a little light-house, the rays of light from which can be directed upon the point which it is desired to illuminate (Figs. 112 and 113).

[Very useful head-lamps, to be attached to the storage battery or galvanic battery, can now be obtained from most of the manufacturers of electrical apparatus in this country. Many of them are, however, very expensive. A very useful chloride of silver battery, designed for the purpose of supplying light for a small hand-lamp, is the Dow portable battery.—Ed.]

GENERAL INDEX.

THERAPEUTIC INDEX.

YOUNG J. PENTLAND'S PUBLICATIONS.

EDINBURGH: 11 TEVIOT PLACE.

LONDON: 38 WEST SMITHFIELD, E.C.

1895.

In 2 *Volumes, large 8vo, Cloth, pp.* xvi., 1008, *illustrated with Maps and Charts. Price* 31s. 6d.

GEOGRAPHICAL PATHOLOGY.

An Inquiry into the Geographical Distribution of Infective and Climatic Diseases.

BY ANDREW DAVIDSON, M.D., F.R.C.P.Ed.,

LATE VISITING AND SUPERINTENDING SURGEON, CIVIL HOSPITAL; PROFESSOR OF CHEMISTRY, ROYAL COLLEGE, MAURITIUS.

(1892.)

EXTRACTS FROM PRESS NOTICES.

"In these two large handsome well printed volumes Dr. Davidson essays a laborious and difficult task, viz., a general survey of the distribution of infective and climatic diseases throughout the globe. Only those who have personally worked in this field of inquiry can adequately realise the immense difficulties which beset the task to which Dr. Davidson has addressed himself, difficulties arising out of scanty, imperfect, and often untrustworthy sources of information, different methods of registration, anomalies in medical nomenclature, and from other causes. We have carefully studied Dr. Davidson's volumes, and we regard them as an important contribution to the study of a vast and complex subject, and likely to find a useful and honourable place in medical literature. The style is easy and clear, the information is well marshalled, the writer seems laudably free from bias, and the printing and appearance of the work leave nothing to be desired. . . . He has made a very substantial contribution to the study of the geographical distribution of disease, and has produced (so far as we know) the best work on the subject hitherto published in the English language."—*The Lancet.*

"The gigantic task—how gigantic this is, those who have engaged in similar studies alone can form any conception—Dr. Davidson set himself has been admirably carried through. His work is a credit to English medical literature. The labour involved in the production of this work must have been prodigious; no less remarkable are the literary skill, the scientific spirit, and the temperance and clearness of judgment in collecting and arranging material and drawing inferences. Dr. Davidson may be congratulated, not only on having written a very learned work, but also on having written a very useful one, whose place on the bookshelf is, beside *Hirsch*, to which it forms a worthy and very necessary companion."—*Practitioner.*

EXAMINATION QUESTIONS

Set for the Professional Examinations in Edinburgh University during the past ten years, selected from the Calendars.

BY W. RAMSAY SMITH, M.B., B.Sc.

NATURAL HISTORY, *arranged and annotated, price* 1s.

BOTANY, *arranged and annotated, price* 1s. 6d.

CHEMISTRY, *answered and annotated, price* 2s.

ANATOMY, *answered and annotated, price* 2s.

MATERIA MEDICA AND THERAPEUTICS, *answered and annotated, price* 2s.

PHYSIOLOGY, *answered and annotated, price* 2s.

MIDWIFERY AND GYNÆCOLOGY, *answered and annotated, price* 1s. 6d.

SURGERY, *answered and annotated, price* 2s.

PRACTICE OF PHYSIC, *answered and annotated, price* 2s.

*** OTHER VOLUMES TO FOLLOW.

Fourth Edition, Revised and Enlarged, 8vo, Cloth, gilt top, pp. xx., 676, *with Woodcut and* 9 *double-page coloured Illustrations. Price* 21s.

DISEASES OF THE SKIN.

A Manual for Students and Practitioners.

BY

W. ALLAN JAMIESON, M.D., F.R.C.P.Ed.,

EXTRA PHYSICIAN FOR DISEASES OF THE SKIN, EDINBURGH ROYAL INFIRMARY; CONSULTING PHYSICIAN EDINBURGH CITY HOSPITAL; LECTURER ON DISEASES OF THE SKIN, SCHOOL OF MEDICINE, EDINBURGH.

(Pentland's Medical Series, Volume First.)

(1894.)

EXTRACTS FROM PRESS NOTICES.

"This is the first volume in *Pentland's Medical Series.* It does credit to the author, and is an excellent book of its kind, sound in matter, thoughtful, and practical. The work is especially noticeable for the excellent style of the author's writing, and for a more complete exposition of the uses of many remedies and methods of treatment brought forward in recent years than is to be found in any other work. Dr. Jamieson is an enthusiastic supporter of Unna's methods and preparations, and not without good reason. The author's experience on this matter will be very acceptable to the profession in these islands. After a careful perusal of the work, we can heartily recommend it."—The Lancet.

"The chief charm of the work, as a whole, is its literary style. It is refreshing to read such vigorous, lucid English, without one ambiguous line. It reminds us more of Watson's *Physic* than any more recent work. We have had the greatest possible pleasure in reading this book. It was Lord Bacon who said that 'some books are to be tasted, others to be swallowed, and some few to be chewed and digested.' This classical work, by Dr. Jamieson, is one of the last class, and as such we strongly recommend it to the profession."—British Medical Journal.

"Dr. Jamieson's work on *Diseases of the Skin* appears as the first volume of *Pentland's Medical Series*, and it is difficult to imagine that a series of medical manuals could have been introduced more successfully and with greater promise. So many manuals on diseases of the skin have lately been published, that a new one, to possess any claim to be read, must afford evidence of individuality. A strong claim to individuality may successfully be made in connection with the book before us. Whilst one of its leading features is that it contains references to the most recent works on dermatology, even up almost to the very date of publication, it also illustrates types of skin disease and methods of treatment that have been observed and studied by Dr. Jamieson himself. It was becoming that the Edinburgh school should produce a work of this kind, and the industry and ability of the author have contributed to the production of a book which does that ancient school of medical learning credit. We must refer the reader to the work itself, which we cordially recommend to his consideration and study."—Practitioner.

"Dr. Allan Jamieson is well known to all our readers by his most valuable periscope of Dermatology, which so often adorns our pages, as well as by much excellent original work. The book seems to fulfil, in a very admirable way, all the purposes for which it is intended. It is full, yet concise enough not to be unwieldy. It is arranged in a thoroughly scientific manner, and yet is severely practical. Without undervaluing the labours or neglecting the classifications of other writers, Dr. Jamieson gives his own opinions, and in his own way. Excellent illustrative cases give a personal interest to the descriptions, and each variety of disease is so carefully painted in words as to render recognition easy; and then the treatment, both local and constitutional, of each is given in the plainest and easiest terms. We congratulate Dr. Jamieson and the Edinburgh School, in which he is such a favourite teacher, on his admirable work."—Edinburgh Medical Journal.

"If the practitioner's library is to contain only one book on diseases of the skin, it would be well furnished with this book."—Bristol Medical Journal.

"In the limits of a short review, it would be impossible to do full justice to this important treatise on dermatology. We can strongly recommend the work as a standard textbook on diseases of the skin, and one which will not only prove useful to the student, but will also serve as an excellent work of reference for the practitioner. All the illustrations are well executed."—Liverpool Medical Journal.

Subscription **One Guinea** *per annum, in advance, post free.*

THE
JOURNAL OF PATHOLOGY
AND BACTERIOLOGY

EDITED, WITH THE COLLABORATION OF DISTINGUISHED BRITISH AND FOREIGN PATHOLOGISTS,

By GERMAN SIMS WOODHEAD, M.D.,

DIRECTOR OF THE LABORATORIES OF THE ROYAL COLLEGES OF PHYSICIANS (LONDON) AND SURGEONS (ENGLAND).

ASSISTED IN SPECIAL DEPARTMENTS BY

SIDNEY MARTIN, M.D. (LOND.) (*Pathological Chemistry*);
M. ARMAND RUFFER, M.D. (OXON.) (*Morbid Anatomy and Histology*);
S. G. SHATTOCK, F.R.C.S. (*Morbid Anatomy*);
C. S. SHERRINGTON, M.D. (CANTAB.) (*Experimental Pathology*);
G. E. CARTWRIGHT WOOD, M.D. (EDIN.) (*Bacteriology*).

IT has been felt for some time that the want in this country of a Journal dealing specially with General and Experimental Pathology has militated most seriously against the free interchange of ideas, not only between English-speaking pathologists, but also between British and Foreign workers.

Although the Transactions of the Pathological Society deal with communications which are brought before its members, there is no medium in which longer articles, and especially those from workers throughout the United Kingdom and abroad, can be brought before a less limited circle of readers. It has been thought desirable, therefore, to found a Journal specially devoted to the publication of original contributions on General Pathology, Pathological Anatomy, and Experimental Pathology, including Bacteriology. These articles will, of course, be mainly from British Laboratories and Hospitals; but the co-operation of many distinguished Continental, American, and Colonial Patho-

EDINBURGH AND LONDON: YOUNG J. PENTLAND.

logists has been obtained, and papers written or edited by them will be placed before our readers.

In order to increase the interest and extend the usefulness of the Journal, it is intended that, in addition to original articles, critical summaries of work done in special departments of Pathology and Bacteriology shall from time to time be published. All articles appearing in the Journal will be signed.

The Journal will appear at least four times a year, but it will be issued more frequently if necessary, in order to ensure publication of all papers as early as possible after they are received.

The numbers issued throughout the year will form a volume, royal 8vo, of about 500 pages. It will be printed on good paper, and will be freely illustrated with Woodcuts and Chromolithographs.

Amongst those who have already promised to collaborate are the following:—

Sir Henry Acland, Bart, Oxford.
J. G. Adami, Montreal.
S. Arloing, Lyons.
B. Bang, Copenhagen.
Alex. Barron, Liverpool.
W. H. Barrett, Belfast.
J. Rose Bradford, London.
Ch. Bouchard, Paris.
H. Buchner, Munich.
Angelo Celli, Rome.
Sir Charles Cameron, Dublin.
A. B. Charrin, Paris.
A. Chantemesse, Paris.
A. Chauveau, Paris.
W. Watson Cheyne, London.
H. Chiari, Prague.
Joseph Coats, Glasgow.
W. T. Councilman, Baltimore.
D. D. Cunningham, Calcutta.
D. Drummond, Newcastle.
S. Delépine, Manchester.
J. Dreschfeld, Manchester.
Von Esmarch, Koenigsberg.
Ch. Firket, Liege.
R. H. Fitz, Boston.
P. Grawitz, Griefswald.
W. S. Greenfield, Edinburgh.
E. H. Hankin, Agra.
H. Heiberg, Christiania.
Victor Horsley, London.
F. Hueppe, Prague.
J. W. Hulke, London.
O. Israel, Berlin.
E. H. Jacob, Leeds.
E. Klebs, Zurich.
Alfred Lingard, Poonah.
Sir Joseph Lister, Bart., London.
O. Lubarsch, Rostock.
P. Marie, Paris.
E. Metchnikoff, Paris.
F. W. Mott, London.
E. Nocard, Alfort.
T. Oliver, Newcastle.
J. Orth, Göttingen.
Wm. Osler, Baltimore.
T. Mitchell Prudden, New York.
J. F. Payne, London.
J. M. Purser, Dublin.
C. S. Roy, Cambridge.
J. C. Salomonsen, Copenhagen.
A. M. Stalker, Dundee.
J. Burdon Sanderson, Oxford.
J. Lindsay Steven, Glasgow.
H. Stilling, Lausanne.
I. Straus, Paris.
T. P. Anderson Stuart, Sydney.
R. Thoma, Dorpat.
J. Batty Tuke, Edinburgh.
L. Vaillard, Paris.
Rud. Virchow, Berlin.
H. Marshall Ward, Cooper's Hill
C. Weigert, Frankfort a/M.
A. Weichselbaum, Vienna.
W. H. Welch, Baltimore.
Samuel Wilks, London.
A. E. Wright, Netley.
Von Zenker, Erlangen.
E. Ziegler, Freiburg.

EDINBURGH AND LONDON: YOUNG J. PENTLAND.